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THE FRACTIONAL PRECIPITATION OF SULPHIDES.[1]

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For the purpose of elucidating the processes which have resulted or are now operating in the formation of ores, laboratory experiments may be made under many widely varying conditions. The most useful experiments, however, will be such as approach most closely to natural conditions. One fundamental condition which has been imposed upon chemical operations in nature is a pressure greater than atmospheric; another condition frequently imposed is elevated temperature. Nevertheless, chemical changes very important in the formation of ores have occurred or are now occurring in regions where the pressure is not great and the temperature not very elevated. Moreover, the influence of pressure slightly greater than atmospheric upon most chemical equilibria is practically negligible. Hence the laboratory reproduction of natural conditions in these two respects is fortunately not difficult.

A chemical condition of such significance in connection with most deposits of sulphide ores is the preponderance of the sulphides of iron. On account of this fact certain experiments of H. N. Stokes upon the action of pyrite and marcasite upon various solutions are very important.[2]

It has occurred to me that there may have been fields of dep-

[1] Published by permission of the Director of the U. S. Geological Survey.
[2] ECON. GEOL., II., 14, 1907.

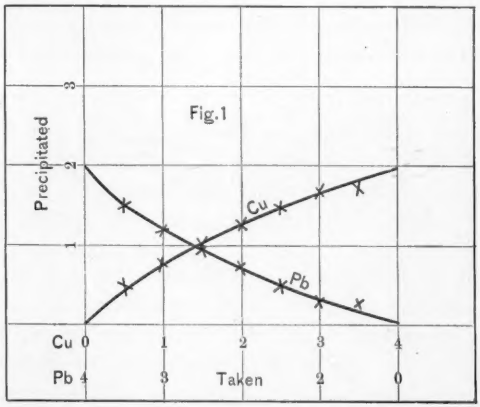
osition where, for a time, at least, the metals, as cations, may have been in excess of the precipitating sulphide anion. This would be a condition somewhat different from that obtaining in analytical chemistry when it is sought to completely precipitate a metal, for the accomplishment of which the essential requirements are known in most cases. Moreover, a mixture of several metals in dilute solution would better accord with natural conditions than a single pure salt. Accordingly it has seemed desirable to study the precipitation of the sulphides of some of the ore-forming metals with these points in view. As is well known, the precipitibility of the various sulphides in a mixture of metals in solution depends enormously upon the acidity or alkalinity of the solution. For example, in an ever so slightly *acid* solution any amount of hydrosulphic acid added to a mixture of the sulphates of iron and copper precipitates only copper sulphide. This is not strictly a fractional precipitation. A fractional precipitation would be obtained with an insufficient amount of precipitant under conditions which would permit all the metals to be precipitated with an excess. In the case of iron and copper sulphates, for example, a *fractionation* might be made with $(NH_4)_2S$ in a *neutral* solution for an excess of $(NH_4)_2S$ would precipitate both sulphides completely.

My first experiments showed that the composition of the precipitate depends a great deal upon the manner of precipitation and time of standing. For example, a mixture of the nitrates of lead and copper partially precipitated with a solution of hydrosulphic acid in the cold and filtered shortly yielded a precipitate containing the sulphides of both metals. The relations are shown in Table I. and Fig. 1. It was intended to precipitate exactly half of the metal in solution, either copper or lead. The quantities of nitrates taken and the metals found are expressed in milli-equivalents, an equivalent being equal in grams to the molecular weight of the substance reduced to a univalent basis.

In viewing these results it is evident that the sulphide of copper had a greater tendency to precipitate under the conditions of the experiments than the sulphide of lead. It was soon discovered that equilibrium was not immediately attained in the

TABLE I.

Milli-eq. $Cu(NO_3)_2$ taken in 40 c.c.	Milli-eq. $Pb(NO_3)_2$ taken.	Milli-eq. Cu in Ppt.	Milli-eq. Pb in Ppt.
0.00	4.00	.00	2.00
0.50	3.50	.50	1.47
1.00	3.00	.78	1.19
1.50	2.50	.95	1.02
2.00	2.00	1.27	.73
2.50	1.50	1.49	.48
3.00	1.00	1.69	.29
3.50	0.50	1.72	.26
4.00	0.00	2.00	.00



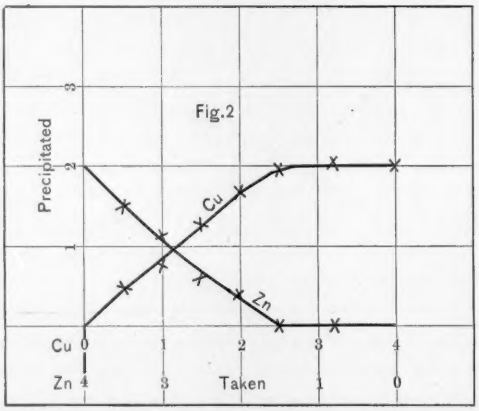
cold. This was owing to the great insolubility of the sulphides. It may be imagined that particles of lead sulphide thrown down by the first mixing of the solutions were too insoluble and sluggish to react in the cold with copper nitrate, although the solution clarified itself completely. The equilibrium approached on warming showed that chiefly *copper was precipitated even at the expense of the lead sulphide* first formed. This could be brought about by using an excess of PbS.

In a flask 50 c.c. of $Cu(NO_3)_2$aq was boiled with 0.200 gm. of precipitated, well washed PbS (with return condenser). The copper in solution decreased from 0.158 to 0.109 in 50 c.c. There was found plenty of lead in the solution and the precipitate, after thorough washing, yielded 0.0391 gm. copper.

Another 50 c.c. of $Cu(NO_3)_2$aq was treated with 0.100 gm. PbS at ordinary temperature. After shaking and filtering, H_2SO_4 gave a ppt. in the filtrate and copper decreased from 0.158 to 0.148 in 50 c.c., showing the same effect occurring slowly in the cold.

One gram of PbS was placed in 50 c.c. $CuSO_4$aq containing 0.0158 gm. Cu and the solution boiled 15 minutes in an atmosphere of hydrogen. After cooling it was found that *the copper had been removed from solution* and that lead had gone into solution.

The above experiments were repeated, using powdered galena and covellite with similar results. The galena was dissolved by



$Cu(NO_3)_2$ with precipitation of CuS. The covellite was unattacked by $Pb(NO_3)_2$ and PbS was not precipitated.

The reaction in the above experiments is therefore

$$PbS \text{ (in excess)} + Cu(NO_3)_2 = CuS + Pb(NO_3)_2$$

A better illustration of selective precipitation was obtained with mixtures of $CuSO_4$ and $ZnSO_4$, precipitated by $(NH_4)_2S$, shaken and filtered. The data are given in Table II and the curves in Fig. 2. The evidence is very clear here that even in

alkaline solution more CuS is precipitated than ZnS. As before, but with an excess of ZnS, the reaction runs

$$ZnS + CuSO_4 = CuS + ZnSO_4$$

TABLE II.

Milli-eq. $CuSO_4$ taken in 40 c.c.	Milli-eq. $ZnSO_4$ taken.	Milli-eq. Cu in Ppt.	Milli-eq. Zn in Ppt.
0.00	0.00	0.00	2.00
5.0	0.50	.49	1.51
1.0	3.00	.87	1.13
1.5	2.50	1.29	.60
2.0	2.00	1.70	.41
2.5	1.00	1.97	.02
3.2	0.80	2.05	.00
4.0	0.00	2.00	.00

These results are stated fully as illustrations of relations which hold in most cases of pairs of sulphides. Both precipitate together at first, then one largely redissolves, leaving the sulphide radical in combination with a single metal. Certain exceptions will be discussed later.

The above facts may find application in theories of the formation of ores. Supposing that large bodies of precipitable solutions come into sudden contact, an indefinite mixture of sulphides will be precipitated. On the other hand, if the solutions, somewhat warmed, react slowly or in any other way opportunity is given for the attainment of equilibrium, the sulphides tend to be precipitated in a definite succession.

The precipitation of soluble salts of metals by the insoluble sulphides of other metals was studied long ago by E. Anthon.[1] He obtained the series: silver, copper, lead, cadmium, iron, nickel, cobalt, manganese. A sulphide of any one of these metals, he found, would be precipitated at the expense of the sulphide of one lower in the series.

The subject was studied further in 1888 by E. Schürmann,[2] who enlarged the series as follows: palladium, mercury, silver, copper, bismuth, cadmium, antimony, tin, lead, zinc, nickel, cobalt,

[1] *J. prakt. Chem.*, *10*, 353, 1837.
[2] *Ann.*, *249*, 326–50, 1888.

ferrous iron, arsenic, thallium, manganese. Schürmann found that some of these transpositions, of which he studied a very large number, occurred more easily than others, particularly those where the metals are widely separated in the series. It was especially difficult to obtain complete transformations in the case of nickel sulphide treated with zinc sulphate, and between thallium salts and the neighboring members of the series. The behavior of iron was peculiar in that the *sulphides of zinc, nickel and cobalt formed at the expense of an excess of ferrous sulphide but they were in turn dissolved when treated with ferrous sulphate.* The positions of arsenic, tin and antimony in the series were also based upon rather incomplete transformations.

This series of metals has been of great importance in considering the development of sulphide ores. It indicates the order of deposition of sulphides from a mixture of metallic salts when such a mixture comes into contact with an excess of sulphide, *e. g.*, iron sulphide. The first metals of the series will be precipitated first, the *solution* will be richest in the last members of the series. An observed succession in the field may therefore indicate either the direction of the flow of the solution which produced the deposition or the direction in which to seek the more precious metal.

Schürmann was chiefly interested in determining the place of each metal in the series. He considered the series to represent the order of the "affinities" of the metals for sulphur. The real explanation seems to be that the series represents the *order of solubility* of the sulphides under the conditions of the experiment. Briefly stated a less soluble salt will form at the expense of a more soluble one. Examples of this are shown by the transposition of barium carbonate into barium chromate in the presence of a soluble chromate, of silver chloride into silver iodide in the presence of a soluble iodide, etc. We may in fact widen Schürmann's observations considerably by correlation with modern ideas of equilibrium.

If the mechanism of the reactions is considered according to

present theories we should have the following scheme of ionization in solution, for the couple silver-copper.

$$\begin{array}{rcl} Ag_2SO_4 \rightleftharpoons & 2Ag^{\cdot} + & SO_4'' \\ & + & + \\ CuS \rightleftharpoons & S'' + & Cu^{\cdot\cdot} \\ & \downarrow & \downarrow \\ & Ag_2S & CuSO_4 \end{array}$$

The actual relations are more complex than this because the ion SH^1 should also be considered. However, the diagram suffices. Every sulphide possesses its "solubility-product," *i. e.*, the product of the concentrations of its two ions which must be exceeded before precipitation can occur. Conversely, if the concentrations of the ions of any sulphide are less than its solubility-product the sulphide will dissolve. Schürmann's series, therefore, gives us the order of the solubility-products or solubilities of the sulphides. This has in fact been beautifully shown by the actual determinations of the solubilities of the sulphides in pure water by Weigel[1]

The idea of the solubility-product allows us at once to explain certain facts noted by Schürmann and to predict others which are usually easily verified by experiment. For instance, it is evidently a matter of indifference in most cases what acidic radicals are present in the solution as long as they do not form insoluble salts with the metals present. Again, the greater speed of adjustment of equilibrium in the case of metals widely separated in the series accords with our present ideas that the speed of reaction is a function of the remoteness of removal from equilibrium. Such facts as that incomplete transformations occur in some cases and that the state of equilibrium depends in other cases upon the quantities of substance taken are to be expected in terms of the theory. If we let K_1 and K_2 represent two solubility-products, and write

$$K_1 = (M_1)\ (S)$$
$$K_2 = (M_2)\ (S)$$

[1] *Z. physik. Chem.*, *58*, 293, 1907.

where (M_1), (M_2) and (S) represent concentrations of metal one, metal two and sulphide, when equilibrium is established, with one common ion, we should have

$$\frac{K_1}{K_2} = \frac{(M_1)}{(M_2)} \text{ or } \frac{(^1W)}{(M_2)} = K_3 \text{ a new constant.}$$

That is, the ratio of the concenrations of the two ionized metals in a solution saturated with both sulphides should be a constant, independent of the quantity of sulphides but probably somewhat dependent on the temperature. Schürmann gave only qualitative results in most cases, and where he says one metal was "completely" removed from solution more exact research would undoubtedly be able to determine it. My own experiments show this.

It will be noted in these experiments that the solution of a sulphide is brought about by the passage of the sulphide ions into a precipitate of another sulphide. The solution may also be brought about, of course, by carrying the metallic ions into a complex ion, *e. g.*, CuS dissolves in KCN, forming the complex ion $Cu(CN)_3''$, and also somewhat in sodium polysulphide, forming a complex sulphide ion.

Although the sulphides of the metals are ordinarily considered to be "insoluble," their solubilities cannot only be measured by physico-chemical methods, but they are, in fact, found to vary to such a degree that mecuric sulphide is over a thousand-fold more insoluble than manganous sulphide.

The above consideration of the solubilities of sulphides helps to explain the phenomena observed by Stokes.[1] He found that pyrite and marcasite were slightly attacked by alkali carbonate, but much more completely when a carbonate of copper, lead, silver or zinc was present. This was because of the greater insolubility of the latter sulphides which formed at the expense of the sulphide of iron in the pyrite and marcasite. The salt of iron in the alkaline solution was of course precipitated as hydroxide. An acid solution would probably have caused an even faster attack.

[1] Econ. Geol., II., 19, 1907.

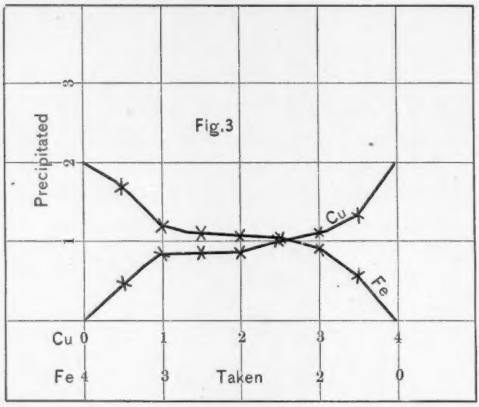
One of the objects in mind in making my fractional precipitations was to throw light upon the conditions of formation of complex sulphides or compounds, such as chalcopyrite. In discussing the relation of ore-deposition to physical conditions, Lindgren has pointed out that chalcopyrite near the surface is "stable under certain conditions," and accordingly classifies it as a "persistent mineral," *i. e.*, one persistently found from igneous conditions up to near the surface.[2] I wished to find out if chalcopyrite could be formed by simple precipitative reactions.

The exceptional behavior of iron has already been mentioned, as observed by Schürmann. He assumed the formation of $FeNiS_2$ but made no transposition with copper-iron couples. His results are also complicated by the fact that they are expressed in terms of the percentage composition of the solution which is very likely to be meaningless when one constituent is present in small amount. H. Malfatti[1] has described certain complex sulphides of iron of the formula $RFeS_2$ where R is a *univalent radical*. It is evident that iron and sulphur are prone to enter into complexes.

As far as the precipitation of $CuFeS_2$ is concerned, it is a matter of indifference whether it be considered $CuS \cdot FeS$ or $Cu_2S \cdot Fe_2S_3$. If it is a definite and insoluble compound, formed in preference to the single sulphides, its formation would have the effect of removing the constituents from a solution in definite proportions. Such removal might modify curves like those of Figs. 1 and 2 into *lines with horizontal sections* over certain regions, as illustrated in Fig. 3, which is drawn from results at first obtained with mixtures of $FeSO_4$ and $CuSO_4$ precipitated with $(NH_4)_2S$. These results, however, were afterwards found to be due to a combination of circumstances and not to the formation of a compound. The ferrous sulphate solution was prepared by dissolving the hydrated crystals. It was preserved in a flask provided with a siphon attachment in an inert atmosphere and in contact with metallic iron.

[1] *Z. analyt. Chem., 48,* 352, 1909.
[2] ECON. GEOL., II., 124, 1907.

In making the precipitations it was first determined how much ammonium sulphide was required to precipitate 2 milli-eq. of each metal. Slightly more was required to precipitate the iron than for an equivalent amount of the other solution. It was aimed in precipitating, to use exactly one-half the amount of sulphide required to precipitate all the metal present. After pre-



cipitation the solution was shaken and filtered. Aliquot portions of the filtrate were analyzed and the composition of the precipitate determined by difference. The results are given in Table III.

TABLE III.

Milli-eq. $CuSO_4$ taken in 40 c.c.	Milli-eq. $FeSO_4$ taken.	Milli-eq. Cu in Ppt.	Milli-eq. Fe in Ppt.
0.00	4.00	0.00	2.00
0.50	3.50	0.46	1.69
1.00	3.00	0.87	1.19
1.50	2.50	0.87	1.11
2.00	2.00	0.86	1.06
2.50	1.50	1.01	1.03
3.00	1.00	1.11	0.92
3.50	0.50	1.33	0.57
4.00	0.00	2.00	0.00

Although the above results give a strong indication of a tendency towards the formation of the compound, $CuFeS_2$, consid-

erable difficulty was experienced in reproducing them some time after they were first obtained. When Na_2S solution was used a curve of the type shown in Fig. 2 was obtained, showing that *CuS was precipitated in preference to FeS*. The same result was obtained with NH_4SH. Table IV. gives the results with Na_2S.

TABLE IV.

Milli-eq. $CuSO_4$ taken.	Milli-eq. $FeSO_4$ taken.	Milli-eq. Fe in Ppt.
0.00	4.00	1.99
0.25	3.75	1.73
0.50	3.50	1.45
1.00	3.00	.90
1.25	2.75	.85
1.50	2.50	.40
1.65	2.35	.25
1.80	2.20	.14
1.90	2.10	.29
2.00	2.00	.24
2.10	1.90	.28
2.50	1.50	.25
3.00	1.00	.17
3.50	.50	.12
3.80	.20	.14
3.80	.20	.26

The experiments shown in Table V. were made by introducing a measured quantity of H_2S gas into the slightly exhausted precipitating flask containing the hydroxides. The atmosphere in the flask was hydrogen. The H_2S (by volume) was calculated for exactly 2 milli-eq. in each precipitation. Time was given and heat applied to aid in attaining equilibrium.

TABLE V.

Exp.	Milli-eq. NaOH taken.	Milli-eq. $FeSO_4$.	Milli-eq. $CuSO_4$.	Milli-eq. Fe Ppt.	Milli-eq. Cu Ppt.
a	3.0	1	3	1.00	2.55
b	2.5	1	3	.80	1.92
c	2.1	1	3	.50	1.87
d	1.9	1	3	.22	2.11
e	2.0	4	0	2.38	0
f	0	0	4	0	1.62
g	0	0	4	0	1.60

Several facts are shown in these experiments. If the CuS precipitated in *f* be taken as a measure of the sulphide introduced

there appears to have been some hydrogen in the H_2S. If so, the amount of FeS precipitated in *e* is slightly too large. This may be accounted for by the formation of basic sulphate of iron, or possibly by slight oxidation, although with the precaution used the oxidation could not have been great. In any case, *as the concentration of hydroxide becomes small no sulphide of iron is precipitated when sulphide of copper can be.*

It appeared necessary to obtain some light on the coprecipitation of the hydroxides of iron and copper. The fractionations in Table VI., carried out like those of the sulphides, were made using NH_4OH as precipitant.

TABLE VI.

Milli-eq. $CuSO_4$ taken in 40 c.c.	Milli-eq $FeSO_4$ taken	Milli-eq. Cu in Ppt.	Milli-eq. Fe in Ppt.	Color of in Ppt.
0.00	4.00	0.00	2.43	pale green
.80	3.20	0.80	1.30	black
1.10	2.90	1.08	1.01	black
1.50	2.50	1.03	1.01	———
1.70	2.30	1.08	1.05	brownish
2.00	2.00	1.09	1.07	———
2.50	1.50	1.12	0.97	———
2.85	1.15	1.20	0.95	orange
2.90	1.10	1.26	0.91	orange
3.00	1.00	1.33	0.87	orange
3.20	0.80	1.66	0.68	———
4.00	0.00	2.75	0.00	green

These results show a very marked selective precipitation. At the extreme concentrations basic salts are precipitated, at the medium concentrations apparently a compound containing both iron and copper in the atomic ratio 1 to 1. The results need not be discussed further here, however, as the conclusion suffices for present purposes: *The addition of alkali to a solution containing an excess of salts of copper and iron yields a precipitate containing both metals over all concentrations.*

It is clear from these results that the selective precipitation of sulphide of iron shown in Table III. and Fig. 3 was due to hydroxide, not to sulphide. This was in fact shown by many more experiments which merely strengthened the same conclusion. If in the preparation of the ammonium or sodium sulphide, care was

not used to saturate fully the first half of the alkali with hydrosulphic acid, the fractional precipitation gave iron with copper; but when it was certain that no excess of free alkali was present, only the merest trace of iron was precipitated when copper could be. The same result was obtained with polysulphides of sodium and ammonium containing a high per cent. of sulphur. The curves were in all cases like Fig. 2 except with Fe in place of Zn. Hence it is concluded: *With a neutral solution containing salts of iron and copper, precipitated with an insufficiency of sodium or ammonium sulphide, the copper sulphide forms and is removed from solution before any sulphide of iron is precipitated.* If, by chance, there is hydroxide present in the solution, the iron will precipitate with the copper. Such a mixed complex precipitate might under certain conditions be altered by heat subsequently into chalcopyrite. But with the exception of this possibility the formation of chalcopyrite by precipitative reactions at moderate temperatures and pressures demands at least more precipitating sulphide than corresponds to the copper present; otherwise no iron will be precipitated.

By microscopic examination of the lean Butte ores, J. F. Simpson has shown that the pyrite contains the copper as the copper minerals, chalcocite, bornite, chalcopyrite, and enargite, and that of such minerals, chalcopyrite is the oldest.[1]

These ores were probably not formed under conditions of moderate temperature and pressure, but in any case the sulphide was in such great excess that the iron and copper would necessarily be precipitated together.

The above chemical facts are chiefly applicable in processes of secondary enrichment. Here they would indicate that mixed iron and copper sulphides would contain the simple sulphides of copper, but not chalcopyrite. If chalcopyrite is found it would appear to indicate either an excess of precipitating sulphide, with reference to the copper present at the time of its formation, or conditions of formation very different from those in the above precipitative reactions.

[1] ECON. GEOL., III., 635, 1908.

SUMMARY.

A study was made of the fractional precipitation of pairs of metallic salts by less than their chemical equivalent of soluble sulphide. In every case one of the two possible sulphides was found to form in preference to the other under the conditions of the experiment. Contrary to expectations the formation of compound sulphides was not detected by this method. Particularly where it was thought that a precipitate of the composition of chalcopyrite might separate it was found that practically no iron was precipitated until the copper was exhausted from solution. This would at least suggest that secondary "cupriferous pyrite" would be more apt to hold its copper as admixed chalcocite than as chalcopyrite. Not all the possible couples have yet been studied, but so far it is held, according to present theories, that the order of selective precipitation depends upon the solubilities of the sulphides. These solubilities, though all small, have a wide range among themselves. The more insoluble sulphide forms at the expense of the soluble one. Thus it is pointed out that Schürmann's series of affinities of the metals for sulphur is practically identical with the order of solubilities as determined by Weigelt. The method of fractional precipitation differs from the method of Schürmann in that all ranges of concentrations are considered. It was shown that the hydroxides of iron and copper differ from the sulphides in that both hydroxides are precipitated over all concentrations. The fractional precipitation of these and similar mixtures is being continued.

SUPERFICIAL ALTERATION OF THE BUTTE VEINS.

RENO H. SALES.

CHARACTER OF OUTCROPS.

The outcrops of the Butte copper veins are indistinct and can rarely be traced upon the surface for more than a few yards. In some instances, notably the Anaconda, Colusa and Syndicate veins, they do actually project above the wash, or debris. As a general rule, in the central copper area, the tops of the veins are found only by digging through this covering, which varies in thickness from two or three feet up to twenty feet. An exceptional thickness of debris is found on the flat area east from the Silver Bow and Leonard mines, where it is known to be as much as two hundred and fifty feet over a large area. This unusual development is probably due to the influence of the big Continental Fault which runs in a north and south direction along the base of the East Ridge and is supposed to be of comparatively recent age.

The fresh unaltered granite is more resistant to the action of atmospheric agencies than the altered granite, and owing to this fact, veins or fault outcrops found within fresh granite are often readily traced over the surface, their presence being indicated by a belt or zone of finely disintegrated, brown or reddish-yellow rock, in which are usually found variable quantities of oxidized vein quartz and iron oxides. Where, in such cases, the granite between the veins is not altered, as in the vicinity of the Jessie, Gem, and mines lying north from the Speculator and Corra, the surface is characterized by the presence of large boulders of unaltered granite, usually in heaps or piles, similar in appearance to the general surface features over the whole of the Boulder granite area.

The alteration of the granite in and adjacent to the copper veins strongly manifests itself by smooth surfaces, the natural result of

weathering of soft altered rock. When exposed to the action of atmospheric agencies, rain, wind and frost, the more highly altered material disintegrates, and, owing to the ever present iron pyrite, becomes stained to a reddish-yellow or brown color. It follows that, to some extent at least, the degree of discoloration of the oxidized material depends upon the amount of iron pyrites present in the veins and country rock.

In the central copper area, that is, in the vicinity of the Anaconda mine and to the eastward, there are but few if any actual outcroppings of bed-rock, everything being effectually concealed by the covering of surface debris. This debris consists of iron-stained altered granite, in the form of sand and small angular fragments, together with all manner of fragmentary vein quartz, aplite and quartz-porphyry. The clusters of rounded boulders so characteristic of the normal weathering of granite are entirely absent.

The resistance offered to atmospheric agencies by granite altered by vein-forming action, is largely dependent upon the intensity or degree of alteration, and upon the amount of silicification and pyritization. A highly altered variety in or near a vein or fault and showing but little, if any silicification, is readily disintegrated when exposed at the surface. The addition of silica, in the form of quartz causes a strengthening to a marked degree, so that in the case of a vein of practically pure quartz, the most resistant product is obtained, which may project above the surface wash as a visible outcrop.

Almost without exception the copper veins are barren of copper at the outcrop, this being true also of the zone of oxidation below. There are no visible copper minerals of any kind, oxides, carbonates or silicates, and it rarely occurs that an assay of the oxidized material will show more than a trace of copper. As a marked exception to the general absence of copper in the oxidized portions of the veins, mention may be made of small quantities of carbonate and oxide ore with native copper, found in the Parrot vein near the surface in the Gagnon mine. Small amounts of native copper have also been found in the eastern part of the district in the Modoc and Silver Bow mines, but not in sufficient

quantities to constitute an ore. A peculiar occurrence of copper silicate ore in the Bullwhacker mine will be described later in this paper. Taking a broad view of the entire copper producing area, it can be stated that there is but little, if any, positive evidence to be found in those portions of the veins nearest the surface, that is, the oxidized material, to indicate the existence of copper in commercial quantities or otherwise at greater depths.

The silver content in the oxidized or free-milling ore runs from a trace up to thirty ounces. In some instances the veins of the East-West system were earlier worked for silver ores. This is true, however, only in the case of the larger veins, notably the Anaconda, Colusa, Pennsylvania No. 1 and Syndicate. Gold is quite uniformly distributed throughout the entire copper area, but in small amounts, roughly, fifty cents per ton, with but little variation in quantity between the oxidized and sulphide ores. There appears to have been a concentration of silver content in the oxidized zone, and it is found that the oxidized ore often runs higher in silver than the sulphide ore lying below.

By means of the physical and mineralogical characters of their outcrops, the veins of the Butte district can be divided, in a general way only, into three classes, namely:

1. Copper veins.
2. Fault veins, which may be either copper or silver producing.
3. Silver veins.

Between the copper and fault-copper veins the shading from one into the other is so gradual that they cannot often be distinguished by means of shallow surface openings. The fault vein is usually recognizable by the presence of characteristic fault clay and crushed granite, while the quartz-pyrite veins of the East-West, or Anaconda system, are almost entirely lacking in these features, and generally show by comparison much larger amounts of quartz and iron oxides. The faults and fault veins being much less mineralized and consequently more easily disintegrated, the position of the outcrop is sometimes marked by a depression or ravine, but this cannot be regarded as universally true, and it does not appear that the faulting has had a very

pronounced influence upon the topography of the copper area. The prominence of the Rarus and Modoc ridges is due to the presence of the more resistant quartz-porphyry dikes, which form in each case the backbone of the ridge.

The outcrop of a typical Butte copper vein of the East-West system consists of altered vein granite, quartz and oxides of iron, chiefly limonite. The exact composition and physical character of this upper portion of the vein depends upon its mineralogical composition before oxidation. There may be present a small thickness of clay gouge or crushed granite within or along the vein boundaries. The granite adjacent to the vein is irregularly stained with iron oxide, particularly along fractures and seams.

The oxidized outcrop of a fault vein, such as the veins of the Blue Vein system, consists of an iron stained mass of crushed white, soft granite, with one or more seams of leached fault clay of a yellowish white or violet color. There may be present, also, larger or smaller quantities of iron-stained quartz.

In strong contrast to the uncertain and ill-defined copper vein outcrop are the bold projecting outcrops of the manganese-silver veins, which may be traced for hundreds, or even thousands of feet over the surface. Many of them, for example, the Rainbow, Emma, Travona, Silver Lick, Valdmere, Black Rock and numberless others, stand out in bold relief from one to ten feet above the ground surface. While it is not always true that these veins project above the wash, their presence is very generally indicated by an abundance of float rock. No manganese-silver veins occur within the main copper area, although they are found in abundance on all sides almost entirely surrounding the copper veins. The outcropping portion or the oxidized zone of a typical manganese-silver vein consists chiefly of quartz, oxides of iron, manganese, and calcite. As an original mineral of the unoxidized vein, iron pyrite is not as abundant as in the copper veins, nor is it so universally present. In the copper veins, the minerals quartz and pyrite greatly predominate and they are present in approximately equal amounts. In the unoxidized portion of the silver veins in the order of their relative abundance, are quartz, rhodochrosite, rhodonite, sphalerite, pyrite, calcite and galena.

In the silver vein area there is practically no alteration of the granite except within the veins, or in close proximity to the vein boundaries.

ZONE OF OXIDATION.

By the "zone of oxidation" is meant all of that portion of the veins and country-rock which have been oxidized through the action of descending ground waters. It includes therefore, in vertical extent, all of the ground, veins and country-rock alike, in the zone bounded at the top by the solid ground surface, *i. e.*, the bottom of the wash, and on the bottom by the plane of the upper limit of the sulphides. The depth to which oxidation has penetrated varies between wide limits. In the vicinity of the St. Lawrence and Mountain View mines it is nearly 400 feet, while in many parts of the camp it is as low as ten feet. The depth of oxidation depends largely upon the composition of the country rock, to a greater degree in fact than on the topographic features. The more complete the alteration and pyritization the greater the depth of oxidation. In the central copper area, that is, where the granite is strongly altered and pyritized, the upper limit of sulphides is roughly a horizontal plane, notwithstanding the fact that there are variations of 300 feet in the surface contours over the same area. Over the remainder of the copper area the average depth is approximately fifty feet. The depth of oxidation in the veins is influenced to a slight degree by the physical character of the veins themselves. Under like conditions, a quartz vein will always be found to be oxidized to a greater depth than a fault or fault vein, due to the greater impermeability of the clay and crushed granite of the latter class of veins.

Examined from the surface downward the oxidized portion of a copper vein will show but little variation in physical character or mineral composition between the outcrop and the sulphide ore. The line of separation marking the change from oxidized to sulphide ore is very sharp and clean cut. There is no partial oxidation of the vein; no mixture of sulphides and oxides. The entire change in any single cross-section of a vein

takes place within two or three feet vertically. Generally the sulphide ore through slight changes in the relative abundance of certain minerals, indicates the proximity of the oxides, while in the case of the oxides, there is seldom, if ever, any change to indicate a nearness to sulphides. In the copper belt, the minor veins, stringers, iron pyrite seams, country rock, etc., are all oxidized and bear the same relation to the surface and to depth of oxidation as do the large veins.

In the Bullwhacker mine and vicinity, lying immediately to the east of the Pittsburg and Montana Company's property, twenty-five thousand tons of a green silicate ore have been mined from shallow depths. The ore occurs along the Continental Fault and it appears to be mainly a surface concentration. The crushed granite of the fault was evidently the most favorable locality for deposition of the copper minerals. The ore is a slightly altered granite carrying silicate of copper as a chief constituent, with small quantities of the oxide cuprite and malachite. The copper minerals are found distributed rather uniformly through the granite, imparting to it a blue to olive green color. The granite has lost none of its structure, its biotites and other dark minerals are unaltered, in fact, the ore is a typical Butte granite, stained or enriched by the copper silicate chrysocolla. This occurrence is mentioned here as a variation from the typical copper-free oxidized portions of the veins of the main copper producing area.

In the quartz-pyrite veins of the Anaconda or East-West system the beginning of the sulphides is the beginning of the valuable copper ore. Almost without exception commercial ore is found in these veins as soon as the boundary plane between oxides and sulphides is penetrated. This is characteristic of the veins of uniform physical character, such as those of the East-West series.

The fault veins of the Blue and No. 16 vein series show a wide variation from the above. The ore bodies in these veins occur in shoots which are decidedly irregular in form and extent, and since these shoots often pitch at low angles within the plane of the vein, a vertical cross-section of a fault vein may show ore

only at great depths, if at all. It is possible, therefore, to sink many hundreds of feet below the oxidized zone of such a vein before encountering an ore shoot, which in itself, however, may find its way to the surface at some point along the course of the vein. In some of the fault veins of the Butte District, very large and extremely valuable shoots of copper ore have been opened up, whose upper limit is more than 700 feet below the surface. In such cases there is no direct contact between oxidized vein and commercial ore. In following upwards on the dip of the vein from such an ore shoot the vein consists of only barren crushed granite carrying small quantities of disseminated pyrite and quartz.

THE HOT SPRINGS AT OJO CALIENTE AND THEIR DEPOSITS.[1]

WALDEMAR LINDGREN.

In view of the general interest which attaches to the relation between mineral deposits and hot springs the following notes are published as a small contribution to the subject.

The thermal springs of Ojo Caliente, situated about 50 miles north of Santa Fe, are well known in New Mexico for their curative power and figure in the earliest records of the territory. They issue in the valley of Ojo Caliente Creek, a tributary to the Chama River, which finds its source in the southern slope of the Hopewell Mountains. The easiest access to the springs is from the Barranca station on the Denver and Rio Grande Railroad, about 10 miles east-southeast of Ojo Caliente.

Barranca is situated on the basaltic plateau 1,000 feet above and 2 miles west of Rio Grande. Below the basalt flow lie the white sandy and even-grained deposits of the Santa Fe marl. The road to the springs soon descends the escarpment of the basaltic mesa, and from this point to the springs extends a wide sandy valley, merging on the south with the valley of the Chama. It is entirely covered by the Santa Fe marl, which underlies the basalt and which presents the uniform and thinly bedded characteristics of lacustrine beds. At every favorable exposure this thin bedding is observed and it has usually a well-defined dip of 20° to 35°. At the springs, which issue on the western bank of the stream, these lake beds are distinctly tuffaceous, sandy and gravelly; the tuff appears to be of andesitic character.

Immediately behind the springs rises a bluff of gneissoid reddish rock, 100 feet high. After ascending this the trail to the mineral deposit crosses a little flat mostly covered with sand and about 4,000 feet wide. Beyond this rises boldly a range of

[1] Published with the permission of the Director of the Geological Survey.

hills of reddish gneiss, forming a southerly outlier or extension of the Hopewell Mountains, which consist of pre-Cambrian rocks. The highest points are probably at least 1,000 feet above the springs. The trail follows up a prominent gulch in these hills and the spring deposit is reached at an elevation of about 500 feet above the springs. A small shaft is located on the brow of the hill, south of the gulch, and about 200 feet higher than its bed. A tunnel is driven in the side hill 150 feet lower than the shaft and only a few hundred feet distant horizontally. This tunnel has not yet reached the deposit. Nearby are some irregular excavations which are believed to have been made by aid of fire setting during the early part of Spanish occupancy. These openings, it is stated, were driven on a stringer of the main deposit.

The country rock of the bluff behind the springs and the whole range of hills so far as examined is a reddish fine-grained gneiss, with foliation striking N. 45° E. and traversed by dikes of coarse pegmatite. The microscope shows it to be a mosaic of quartz and othoclase with a few larger quartz grains; in places it contains microcline, albite, and microperthite in small grains. The gneissoid structure is shown in the parallel arrangement of small flakes of greenish brown biotite or small foils of muscovite.

The shaft is sunk on a distinct vein, in gneissoid rock. The strike of the vein is N. 70° E. and the dip 70° N. N. W.; its width is 2 to 3 feet, and it is traceable for about 200 feet on each side of the shaft. The walls are fairly defined, but the fissure is full of rock fragments which are loosely cemented by crusts of colorless fluorite. The mineral is not readily recognized, for besides being colorless it has a coarsely fibrous structure, perpendicular to the fragments of rock which it encrusts; it looks somewhat like aragonite. The vein matter is oxidized, containing limonite and oxide of manganese, the latter reported to contain silver. Two stringers filled with fluorite come in from the footwall side. From the dump of the tunnel were obtained some little stringers in gneiss, filled with greenish fluorite of normal appearance and occasional crystals of barite (011.110.100 according to

W. T. Schaller). The fissure-filling is reported to contain gold and silver. The owner, Mr. Antonio Joseph, who also is the proprietor of the springs, states that the best assay returns yield $75 in silver and $30 in gold to the ton, other returns giving, for instance, $4 in gold and $1 in silver, and there is no reason to doubt that these figures are authentic. Samples of the crusted fluorite ore were assayed with great care by Ledoux and Company of New York, and yielded traces of gold and silver.

Five hundred feet southwest of the shaft and directly in the line of the vein which can be traced in this direction for 200 feet, is a small hill about 75 feet vertically above the shaft. The top of this hill is covered to the extent of about half an acre by a tufaceous hot spring deposit, probably only a few feet deep. A pit 3 feet deep has been sunk in it. It is a loosely coherent cellular mass, mainly composed of calcite with some limonite. According to Mr. Joseph it contains traces of gold and silver. Three specimens, from the surface, and 2 and 2½ feet below the surface respectively, were assayed by Ledoux and Company with special precautions, and yielded as follows per ton: number 68 Au 0.0008 ounces, Ag 0.08 ounces; number 69 Au 0.0025 ounces, Ag 0.1 ounces; number 70 Au 0.0008 ounces, Ag 0.05 ounces.

A sample of the tufa was analyzed by Mr. George Steiger with the following approximate result:

Insoluble 3 per cent.; Fe_2O_3, Al_2O_3, 2.9 per cent.; CaO 50.8 per cent.; MgO none; CO_2 (calculated) 39.6 per cent.; P_2O_5 none; Fluorine 0.44 per cent.; Arsenic none; barium none. The determination of fluorine was made with particular care. This composition corresponds to about 89.60 per cent. of calcite and 0.9 per cent. of fluorite.

The bluff of gneiss immediately back of the hot springs was found to contain at several places narrow, filled seams of a white mineral which proved to be fluorite.

The conclusions drawn in the field from the facts observed were:

1. That the tufa deposit on top of the hill has been accumulated by the evaporation of hot waters reaching the surface.

2. That the vein formed the conduit through which the hot waters reached the surface and in which calcium fluorite was deposited, while the remaining calcium was held in solution as bicarbonate until reaching the surface. The evidence upon this point is strong, but perhaps not absolutely conclusive. The peculiar structure of the fluorite itself tends to show that it has been deposited under unusual circumstances and probably close to the surface.

3. That the tufa deposit and the fluorite vein had been formed by the Ojo Caliente Springs while issuing at a level several hundred feet above the present springs.

4. That the gulch adjacent to the vein and the whole valley had been eroded since the time when the springs issued at high level.

5. That the fluorite veinlets in the bluff back of the springs, and about 100 feet above them, were formed during the gradual recession of the thermal waters, keeping step with the excavations of the valley.

It is needless to say that the assays and analysis of the spring deposit strengthened these conclusions.

Upon the return from the field it was found that a very careful analysis of the waters of the Ojo Caliente Springs had been made a number of years ago, by Dr. W. F. Hillebrand. Several older analyses, evidently of less accuracy and detail were made by Oscar Loew, analyst of the Wheeler Survey, and they agree well, within limits, with Dr. Hillebrand's work, and show that the composition of the springs is approximately uniform. Their temperature is said to vary from 90° to 122° F.

The analysis follows:

The water also contains traces of arsenic, nitrates, iodine (?), barium and ammonium. No organic matter is present. Titanium, bromine, manganese and sulphides were looked for but not found.

This analysis shows that the water is of the sodium carbonate type with minor amounts of chloride and sulphate of sodium. Particularly remarkable is the large and unusual content of fluo-

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ANALYSIS OF WATER FROM OJO CALIENTE, NEW MEXICO.[1]

BY W. F. HILLEBRAND.

Found. Parts Per Million.		Hypothetical Combination. Parts Per Million.		Per Cent. Total Solids.
SiO_2	60.2	LiCl	20.9	.62
SO_4	151.0	KCl	59.9	1.76
PO_4	.2	NaCl	305.5	9.01
CO_3	2153.5	$Na_2B_4O_7$	5.4	.16
B_4O_7	4.2	Na_2SO_4	223.3	6.59
Cl	231.4	Na_2CO_3	1846.9	54.49
F	5.2	$Ca_3P_2O_8$	.3	.01
Fe_2O_3[2]	1.6	CaF_2	10.7	.32
Al_2O_3	.5	$CaCO_3$	43.0	1.27
Ca	22.8	$SrCO_3$	2.4	.07
Sr	1.4	$MgCO_3$	33.2	.98
Mg	9.5	SiO_2	60.2	1.78
K	31.4	Fe_2O_3	1.6	.05
Na	995.1	Al_2O_3	.5	.01
Li	3.4	CO_2 (bicarbonate)	775.6	22.88
	3,671.4		3,389.4	100.00

rine, corresponding to nearly 11 parts per million of calcium fluoride. The content in boron is also noteworthy. On the whole, it is a strong mineral water distinctly of the type of volcanic springs; *i. e.*, of hot springs that are common in regions of expiring volcanic activity. No one may question the competency of this water to deposit fluorite and also calcite, on the evaporation of excess carbon dioxide.

The evidence of erosion here adduced tends to show that these springs have been active over a very considerable period of time, possibly since the middle or later part of the Tertiary. The material eroded during the recession of the spring level was probably in large part the tuffs of the Santa Fe formation, which once filled Ojo Caliente Valley Near Barranca station the top of these lake beds is at an elevation of about 6,800 feet. The elevation at the present spring is 6,292 feet (Wheeler); consequently it must be admitted that at one time, probably at the close of the Tertiary, the lacustrine beds reached the level of the tuffaceous spring and the fluorite veins.

At the present time the springs issue at the foot of the hill

[1] *Bull. U. S. Geol. Survey*, No. 113, p. 114.

[2] State of oxidation unknown; Fe_2O_3 all in sediment.

or gneiss, but emerge from the soft sands and tuffs. No deposits of consequence can now form where the springs issue, owing to the manner of their utilization for medicinal purposes.

A number of hot springs, particularly those similar in composition to the type described above contain fluorine. Among those richest in this element are the Vichy Springs, some of which contain from 7.6 parts of fluorine per million up to 18 parts per million. The waters of the spring at Bourbon-l'Archambault are stated to contain 2.68 parts per million of fluorine.[1] In very few instances, however, has the actual deposition of fluorite by hot waters been demonstrated. Daubrée[2] mentions only two cases, at the Carlsbad and at the Plombières springs.

[1] Clarke, F. W. The data of geochemistry, U. S. Geol. Survey, Bull. No. 330, 1908, p. 149.

[2] "Les eaux souterraines à l'époque actuelle," 1887, Part II., pp. 19–20.

OXIDATION OF SULPHIDES.

H. A. Buehler and V. H. Gottschalk.

An examination of that portion of any body of sulphide ores occurring within the zone of weathering usually gives ample evidence of extensive solution. The occurrence of oxidized ores in this zone indicates that oxidation has preceded solution and that the transfer of the metal is largely due to the solubility of the metallic salts formed during this process. In most cases, the slight solubility of the natural sulphides precludes an extensive transfer through simple solution. Field evidence is ample to show that under natural conditions the sulphides are oxidized. The relative speed of oxidation, however, has not been definitely determined and the influence of the oxidation of one sulphide upon another is as yet only inferred from field relations. It was for the study of these problems that the experiments cited below were undertaken.

To assign a definite figure for the speed of oxidation of any one sulphide is quite impossible, since the rapidity of the action depends upon the nature and extent of the surfaces exposed, upon the details of the experimental arrangement, as well as upon the incidental variations during the course of the determination.

Under natural conditions it is very probable that certain salts dissolved at or near the surface exert an oxidizing or solvent effect upon the metallic ores and in this way hasten transportation. Without doubt certain impurities in every ore body also materially affect solution, either by direct chemical action or through simple removal, whereby the sulphide becomes porous exposing a larger surface to the action of oxidizing waters. Likewise the occurrence of other impurities may tend to decrease the solubility and thus hinder transportation.

Two recent papers[1] on the oxidation of pyrite, lead to the

[1] Winchell, Economic Geology, Vol. II., p. 290 (1907); Grout, Economic Geology, Vol. III., p. 632 (1908).

conclusion that this mineral is quite slowly oxidized. A somewhat different method of treatment has given us fairly consistent results since its first trial nearly four years ago. Our experiments show not only a measurable oxidation for most sulphides treated, but also indicate that pyrite or marcasite, when mixed with other sulphides, causes a much more rapid oxidation of the second sulphide. We find, for instance, that sphalerite, galena, covellite and enargite are oxidized from eight to twenty times faster in the presence of an equal amount of pyrite or marcasite than when treated alone under the same conditions. Whether or not marcasite and pyrite are the only sulphides acting as an accelerator has not as yet been determined. Experiments are now being carried on to determine this fact.

EXPERIMENTAL.

The apparatus (Fig. 1) consisted of a 6-cm. funnel, fitted with a 4-cm. Hirsch filtering plate on which was spread a double

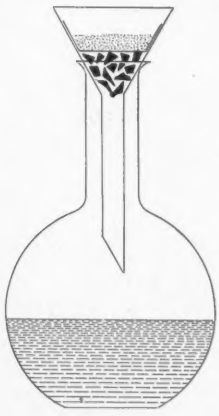

FIG. 1.

layer of 9-cm. S. & S. ash-free filter paper. The filter plate was supported by pieces of broken porcelain. The funnel rested upon the neck of a 700-c.c. Jena flat-bottom flask, as shown.

In the various experiments, the following sulphides were used: pyrite, marcasite, chalcopyrite, sphalerite, galena and covellite (containing some pyrite). The purest minerals available were selected and were especially sorted before being ground to pass a 100-mesh sieve.

The various sulphides were treated alone and when mixed with an equal portion, by weight, of pyrite or marcasite. In series "A," 10 grams of the sulphides were used, while in series "B" and in the case of the copper ores, 5 grams were used. In each experiment the ore was spread evenly upon the filter paper prepared as described above. The sulphides were then washed twice daily with 5 c.c. of distilled water, treatment being continued for about three months. The amount of solution in each flask at the end of the experiment was ordinarily from 400 to 600 c.c. The experimental results follow:

PYRITE.

The evidences of action were manifested soon after beginning the treatment; the filter paper shows yellow stains of oxide of iron; the solution collected in the flask soon assumes a yellowish tint and deposits yellowish brown basic oxide. The filter paper at the end of the experiment was found to be hard and brittle.

	Grams of Iron Washed Through.	Percentage of Iron Washed Through.
Pyrite, Series "A,"	.1185[1]	2.5 per cent.
Pyrite, Series "B,"	.0857	3.7 per cent.

[1] A portion lost.

SPHALERITE.

Alone, the sulphide shows no visible trace of action either on the filter or in the solution. When mixed with pyrite there was a small amount of iron oxide on the filter.

	Grams of Zinc Washed Through.	Percentage of Zinc Washed Through.
Sphalerite, Series "A,"	.0125	.2 per cent.
Sphalerite and pyrite, Series "A,"	.2788	4.2 per cent.

GALENA.

Alone, the sulphide shows no visible trace of action either on the filter or in the solution. When mixed with the pyrite,

oxide of iron occurs on the filter paper; the solution is colorless, but in all such cases a white precipitate of lead sulphate forms in the flask. The precipitate consists of fine tabular crystals.

	Grams of Lead Washed Through in Solution.	Grams of Lead Washed Through in Precipitate.	Percentage of Lead Washed Through.
Galena, Series "A,"	.0005	none	.005
Galena and Pyrite, Series "A,"	.0125	.0504	.7
Galena, Series "B,"	.002	none	.05
Galena and pyrite, Series "B,"	.0111	.0149	.6

COPPER ORES.

In general the evidences of action vary with each ore treated Alone, chalcopyrite gives a slightly bluish colored solution; enargite shows no perceptible action, while the covellite, which contained some pyrite, and the mixed copper ore gave slightly colored solutions. When mixed with marcasite or pyrite all the solutions have a deep blue color, depositing a slightly brownish precipitate in the flask. The chalcopyrite was not treated with pyrite or marcasite. The mixed copper ore contained 48.34 per cent. copper, and 19.33 per cent. iron.

Copper Ores.	Grams of Copper Washed Through	Percentage of Copper Washed Through.
Covellite,	.0905	Greater than 2.7 per cent.
Covellite and marcasite,	.9187	Greater than 27.6 per cent.
Mixed ore,	.0170	0.35 per cent.
Mixed ore and pyrite,	.3288	6.8 per cent.
Enargite,	none[1]	none
Enargite and pyrite	.2169[1]	About 10.0 per cent.
Chalcopyrite,	.0183	About 1.0 per cent.

[1] No arsenic in solution.

In the results cited, only the metallic ion has received consideration. To obtain exact figures covering the oxidation of the iron sulphide in each case will require accurate analyses of the residue remaining on the filter paper. The proportion of ferrous and ferric ions occurring in the solution is no doubt materially influenced by the presence of the organic matter of the filter paper. That some action takes place is indicated by the decomposition of the filter. This factor has been eliminated by the use of asbestos in experiments now in progress. In those

experiments where pyrite was used the solution invariably shows an excess of sulphate ions indicating the presence of free sulphuric acid.

Winchell and Grout have recently published figures on the rate of oxidation of pyrite. They give a maximum of .08 of one per cent. of the sulphide oxidized after a year's treatment, while we obtain an oxidation of approximately 3 per cent. after treating the sulphide only three months. In order to determine if this difference is due to the fineness of grinding or due to the method of treatment, we have recently started two experiments using pyrite of the same size as in the experiments by Grout and by Winchell, ten grams of the sulphide being used in each case. The sulphides were washed three time daily with 10 c.c. of distilled water. While Winchell was unable to make quantitative determinations of the constituents in solution at the end of three months and was unable to find any evidences of solution at the end of one month, we are able to make quantitative determinations at the end of the first week and have made weekly analyses in order to determine the rate of oxidation in each case. The following are our results showing the amount of material oxidized each week, the analyses being started at the end of three weeks' treatment, the solution of the third week only being used in the first case. These analyses usually show a slight excess of sulphur, indicating the presence of free sulphuric acid.

	Through 20 on 40 Mesh.		Through 40 on 60 Mesh.	
Weeks.	$FeSO_4$ Grams.	$Fe_2(SO_4)_3$ Grams.	$FeSO_4$ Grams.	$Fe_2(SO_4)_3$ Grams.
Third	.0016	.0005	.0028	.0024
Fourth	.0011	.0013	.0035	.0016
Fifth	.0009	.0016	.0026	.0041
Sixth	.0009	.0017	.0026	.0026
Seventh	.0015	.0001	.0033	.0074
Eighth	.0009	.0005	.0032	.0024
Ninth	.0010	.0007	.0022	.0011

According to the above results at the end of seven weeks there has been a total oxidation of .0072 gram of iron when using particles the same size as used by Winchell (through 20- on 40-mesh) and .019 gram of iron when using particles the same

size as used by Grout (through 40- on 60-mesh). These figures are 0.107 and 0.28 of 1 per cent. respectively of the original sulphides used. Assuming that the rapidity of oxidation remains uniform throughout the year, we would obtain under our conditions, a total oxidation of 0.8 of 1 per cent., and 1.08 per cent. in that time.

The above experiments indicate to some extent the influence of the fine grinding upon the speed of oxidation and while we realize that by grinding the sulphides to pass a 100-mesh sieve the speed of oxidation has been measurably increased, we do not believe that the general nature of the results is affected by such treatment.

Whatever values are given ultimately for the rate of oxidation of a single sulphide, the results of the above experiments show beyond a doubt that the admixture of pyrite or marcasite with sphalerite, galena or copper sulphides, increases the rate of oxidation of the latter very materially. Whether or not there is a reciprocal action upon the pyrite or marcasite, has not yet been definitely determined.

In the above experiments we have endeavored to place the sulphides under conditions similar to those obtaining in the zone of oxidation; namely, alternate wet and damp periods, sufficient water being used to intermittently wash away the soluble salts formed.

The possible influence of one sulphide upon the speed of oxidation of another, was first called to our attention in the case of lead and zinc ores through field observations in the Joplin district of southwest Missouri. The ore bodies in this district usually show extensive oxidation and solution and in those areas where marcasite or pyrite is present the mine waters usually carry a considerable quantity of zinc.

That fine grinding is not a requisite to perceptible oxidation is shown by samples of marcasite which have been stored in the loft of the Bureau of Geology and Mines for the past few years. At the present time many of these are partly covered by crystals

of ferrous sulphate, which salt also occurs along the cracks and cleavage planes throughout the specimens. The samples are badly disintegrated simply through the medium of moisture in the air. They have not at any time been subjected to usual weathering conditions.

The influence of pyrite and marcasite upon the oxidation of sphalerite is apparent from the analyses of mine waters collected in the Joplin district. The following are taken from a series of ten, and are representative in every way:

	Arkansas.	Victor.	O K	Winslow.
KCl	9.5	6.1	0.0	4.0
K_2SO_4	0.0	0.0	0.0	2.2
NaCl	0.0	1.3	4.5	0.0
Na_2SO_4	130.3	38.5	30.8	14.7
$Al_2(SO_4)_3$ ..	68.3	73.6	3.3	2.2
$CaSO_4$	1528.0	924.6	371.5	59.7
$Ca(HCO_3)_2$..	0.0	0.0	0.0	250.6
$MgSO_4$	Trace	192.6	60.4	0.0
$FeSO_4$	611.9	387.7	2.6	6.4
$ZnSO_4$	586.2	851.7	1.2	0.0
$PbSO_4$	0.04	0.0	0.0	0.0
SiO_2	23.2	23.2	7.4	11.3
H_2SO_4	170.9	251.7	0.0	0.0
CO_2 (free ..	12.0	87.0	19.7	8.8

(Figures indicate parts per million.)

The waters from the Victor and Arkansas mines contain large quantities of free sulphuric acid and ferrous sulphate, and are heavily charged with zinc sulphate. The waters from the O. K. and Winslow mines, on the other hand, which contain no free sulphuric acid and but small quantities of ferrous sulphate, carry only traces of zinc in solution. At other points throughout the Joplin district similar conditions are found and it is very evident that the presence of pyrite or marcasite increases the rate of oxidation.

SUMMARY.

The experiments described in the foregoing pages show: (1) That natural sulphides are perceptibly oxidized by atmospheric air in the presence of water. (2) That pyrite and marcasite

in contact with other natural sulphides greatly increases the rate of oxidation of the latter sulphides. (3) That fine grinding affects the rate of oxidation. (4) That analyses of mine waters from the southwest Missouri lead and zinc district indicate the similarity of natural oxidation processes to those obtained in the laboratory.

SOME COMMERCIAL ASPECTS OF PEAT AS A SOURCE OF CHEMICAL PRODUCTS.[1]

CHARLES A. DAVIS.

It may be a new and somewhat startling proposition to some of the readers of this journal to think of peat, or "muck," as the source of any sort of chemical products. To such, the plan to build a great commercial chemical manufacturing plant involving the investment of at least a half million dollars, by the side of a peat deposit, with the avowed intention of converting the peat into staple chemical products, and likewise to use the peat to furnish the necessary heat and power to do this, must seem visionary in the extreme. Yet such a plant is not only contemplated, but is said to be already well advanced towards completion in Ireland, and somewhat similar ones on scarcely less magnificent scale are reported either at work or in the process of development or in advanced stages of promotion in Germany and other parts of Europe.

The use of peat as a source of certain kinds of chemical products is no new thing in Northern Europe, where extensive bodies of this material exist and have long been used for fuel, for as early as the latter part of the eighteenth century peat was distilled in retorts to secure tar and gas, and since that time experimental work has been carried on in various parts of Europe almost continuously to learn how to use peat most advantageously for making certain chemical substances.

For a time only gas and tar were sought, but about the middle of the nineteenth century, when there was a general awakening to the importance of chemical industries, enterprises based upon the conversion of peat into chemical products of commercial importance were started in considerable numbers, but for various reasons they failed to come up to the expectations of their pro-

[1] By permission of the Director of the U. S. Geological Survey.

moters and after a time ceased to be operated. The most conspicuous of these early plants, from the prominence given them at the time, and since, in the English scientific press, were two large concerns established, one at Kilberry, near Athy, County Kildare, Ireland, and the other at Dartmoor in England. Neither of these plants were commercially successful, largely it was said because of poor management and the desire to make products that showed technical skill and ability, such as paraffine and aniline, that were costly to make but were not salable at correspondingly high prices. The balance sheets published by each of these companies show large favorable balances, but their permanent suspension after short experimental runs seems to show that these balances were anticipatory rather than real. Doubtless a partial cause for the failure of these companies was the lack of knowledge of the value of heat units, and of the means of conserving and utilizing these, that has been gained since their time by hard experience.

The state of the chemical knowledge of the time of these pioneer plants and upon which they were based is fairly indicated by a paper read by Professor Brande in 1851, before the Royal Institution of London; in this he presents the various products to be secured by the destructive distillation of peat as follows: (1) Sulphate of ammonia, (2) acetate of lime, (3) pyroxylic spirit (wood or methyl alcohol), (4) naptha (light) petroleum oils, (5) heavy oils (illuminating oils) and (6) paraffin (white mineral wax). The chemist of to-day would add but two more substances that might be obtained from the peat, and that have now a market value, namely, asphaltum and creosote oil and its derivatives. He might, however, point out the vastly greater and rapidly growing use of the ammonium sulphate in agriculture, the application of the acetic acid derived from the calcium acetate, and of the wood alcohol, to the arts and trades, while the enormous output of mineral oils in various parts of the world has brought about a complete change in the status of the oils mentioned, which formerly constituted a very valuable part of the obtainable products, for although a much greater market for

them exists now than formerly, the price to be had is comparatively low.

The increase in our theoretical knowledge along these particular lines may be small, even in the lapse of sixty years, but the advances made in applied chemistry have been so great within that time that it may be said that a new science has grown up, and with its growth and its application to many trades and arts there has arisen a constantly and rapidly growing demand for the chemical compounds that can be obtained by destructive distillation from wood and other vegetable matter. During the same period, moreover, the science of chemical engineering has developed so that it is now quite possible to make chemical products at a profit, on a large commercial scale, that formerly could be produced only as matters of experiment in the laboratory. Because of these considerations the manufacture of chemical products from peat may well receive a portion of the attention in this country that has been given it abroad. This is especially true in view of the increasing use of power and fuel gases, both of which are easily made from peat, and of the possibilities of making a grade of coke from peat that can be substituted in all of its uses for charcoal, since the claim is made that practically all of the heavy distillates from peat-coking and gasifying retorts and gas-producers can be profitably converted into readily marketable chemical by-products.

The matter has still greater interest from the viewpoint of the technical chemist, because within the past eight or ten years there have been at least four different processes brought out in Europe to utilize peat for the purposes already indicated, that seem well within the possibility of commercial success, and as each of those is now embodied in one or more large plants that have been operated for a time, or are nearly ready to operate, it seems as if success in these directions is already in sight, if not achieved. And if in Europe these things can be done, why not in America?

Moreover, peat is now converted into gas in gas-producers for fuel and power uses with entire commercial success in a steadily increasing number of places in Germany and Sweden; this phase

of the matter although not considered strictly a chemical one, is, as a matter of fact, so closely allied to chemical engineering that it is difficult to draw a line between the two, and presents a phase of the problem of peat utilization in America that is of great economic importance to those parts of the country where peat deposits are found.

Because of these reasons and some others that may appear later, your attention has been called to the subject before you.

At the outset, in taking up a technical problem involving production, in distinction from one in pure science, it must be shown beyond reasonable doubt that the quantity of the proposed product can be guaranteed sufficient to justify the investments necessary to make it, before any inquiry is instituted as to the cost of manufacture per unit.

Applying this test to the question before us, and dealing in round numbers only, after using all available data, the writer estimates that there are in the United States at least 12,000 square miles of workable peat beds that would yield at least thirteen billions of tons of air-dried peat. This great store of raw material is not uniformly distributed over the country, but is confined practically to the states north of the Ohio and east of the Missouri rivers, except for narrow strips along the coasts; on the Atlantic side, extending south to and including Florida and the coastal plains of the Gulf States, and on the Pacific Coast as far south as Southern California. More exactly, the region of the abundant occurrence of workable peat beds includes the whole of New England, New York, Michigan, Wisconsin, Minnesota, and Florida, and parts of the Dakotas, Iowa, Illinois, Ohio, Pennsylvania, the middle and South Atlantic, the Gulf States, and the western parts of Washington, Oregon, and California. It is interesting to note that with very few minor exceptions there is no overlapping of the areas of occurrence of workable peat and the coal fields of the country. It is thus evident that if no other use is made of the peat, there is stored up in it a large amount of fuel in parts of the country where it is needed.

Assuming, without going into the details of the potential value

of the estimated quantities of products and by-products that could be made from the thirteen billion tons of peat, that the possibility of using this material is worth considering, then among other aspects the commercial one is of fundamental interest, because the scientific one was thoroughly examined years ago.

The growth of the use of peat in Europe presents some interesting phases that should be mentioned here, since by reviewing the progress made there a more intelligent opinion can be formed as to its possible use here. The early uses seem to have been entirely for domestic fuel. As the manufacture of iron increased and charcoal became high in price, peat, then peat charcoal, and finally, peat gas were used in its reduction and manufacture. In the same way in the development of manufacturing, the crude, air-dried, cut peat used for fuel for domestic purposes could not be profitably used for steam generation, nor shipped; and machine-peat, made by thoroughly grinding the wet raw material, forming it into bricks, and air drying it, took its place; later, as the need for a less bulky form arose, the peat was briquetted and even converted into charcoal or coke, and more recently still, into fuel and power gas at the bog and transformed into electricity to be used near by or at a distance.

Mention has been made of early attempts to manufacture chemical products from peat and their lack of commercial success. These experiments were not lost sight of in Germany, where every natural resource must be made the most of; nor in England, where great chemical manufacturing plants utilizing a variety of formerly neglected materials have become an important feature of the industrial life of the country. It is natural that there should be received from these two countries, and from Sweden, another nation coming into prominence in manufacturing, accounts of progress from time to time. The progress made has now crystallized into four well defined lines, on such a scale that commercial importance is claimed for all of them, and, if the reports reaching this country from what would seem to be unprejudiced sources are to be relied upon, the claims are fully justified in at least three of them.

The lines mentioned are: (1) The manufacture of peat coke with the recovery of the chemical by-products, in well-planned recovery plants. (2) The manufacture of producer-gas from dry peat with the recovery of by-products, collected in specially designed scrubbers and afterwards refining them in a recovery plant. The use of peat for gas-production without recovery of by-products may also be considered here. (3) The manufacture of producer-gas from wet peat in the presence of excess of steam under pressure, with the recovery of the ammonia in a specially constructed acid tower, as ammonium sulphate. (4) The direct manufacture of ammonium sulphate, acetic acid, and acetone, and paraffine, by burning peat containing from 75 to 80 per cent. of water, that is, just as it is dug from the bog, in a type of furnace designed for the purpose, the chemical compounds secured being the only salable products of the whole series of operations.

THE MANUFACTURE OF COKE AND BY-PRODUCTS FROM PEAT.

The first of these processes, the manufacture of coke or charcoal from peat, with the recovery of chemical by-products, originated in the early days of peat utilization, when peat was charred in heaps, or later in cylindrical, chimney-like furnaces, by the combustion of a part of the charge. By gradual evolution, stimulated doubtless by the poor returns in money and fuel for the expenditure involved in these crude methods, retorts or furnaces heated from the outside replaced the older devices, and attempts were made to decrease the fuel expenditure by burning the gases given off from the retorts to carry on the distillation. The history of the by-products recovery processes is plainly indicated and needs no elaboration here, but it was only comparatively a short time ago, in 1894, that the first commercial plant embodying all of these ideas was erected at Oldenburg, in Germany, under the supervision and patents of Dr. Martin Ziegler. Two other plants designed by the same inventor have followed the building of the first one, and to-day the Ziegler peat coking and

by-products recovery system seems fairly to have earned its claims to commercial life by living.

The plants at Oldenburg, Germany; Redkino, Russia; and Beuerberg, Bavaria, have been so often described in technical journals that only the briefest description of the process embodied in them is needed here. The peat used is dug during the short summer season of about 100 days, to the extent of 30,000 or more tons of air-dried material. It is prepared for coking by grinding it thoroughly while wet in the ordinary type of peat machine, which closely resembles the pug-mill of the brick maker; the machine delivers the macerated peat in the form of bricks which are dried by exposure to the air, and contain 20 to 25 per cent. of moisture when dry. These peat bricks are stored by stacking under cover until used.

The coking is done in vertical retorts made of fire brick and cast iron, and these are connected with condensers for cooling and collecting the liquid distillates from the retorts. The apparatus is so arranged that the heat of the waste gases from the furnaces below the retorts is used not only to do the coking, but also to concentrate the solutions of the by-products. In the most recent of the Ziegler plants these hot gases are turned directly from the flues around the coking retorts into secondary or subsidiary retorts, containing a poorer quality of peat than is used to produce the best coke, which their heat converts into semi-coke or half-coke, sold for fuel. After passing through the condensing apparatus the uncondensed gases from the coking retorts are turned back to the furnaces and burned to carry on the coking operations. It is at once evident that the process after it is once started is self-sustaining and continuous as long as fuel is supplied, and that the fuel economy is much higher than by older methods.

By the Ziegler process a high grade of peat coke, similar in quality and commercial value to good hardwood charcoal, and much superior to coke for metallurgical operations, such as smelting and refining, is the primary product.

The heavier distillates collect in the condensing apparatus, as tar and tar- or gas-water, and from these the chemical by-products are made. The tar yields on proper redistillation:

Substance.	Pounds Per 100 Pounds of Dry Tar.
Light petroleum oils	12
Heavy petroleum oils	25
Lubricating oil	15
Paraffin	2
Asphaltum	16
Creosote	10
Creosote Gas and Loss	23

From the tar-water may be recovered:

Substance.	Per 100 Pounds of Tar Water.	Per Ton Dry Peat Substance.
Acetic acid	1.580	12.640
Methyl alcohol	0.764	6.112
Ammonia	0.086	0.688 = 5.261 $(NH_4)_2SO_4$
Butyric and valerianic acids	0.207	6.656

The quantities of by-products actually obtained for a ton of peat treated by the Ziegler process according to the official report of a test, are as follows:

The peat delivered at the kiln cost $1.19 per metric ton (2,204 lbs.). On coking it yields:

Substance.	Amount in Pounds.	Value in U. S. Currency.
Peat coke	775.6	$3.75
Tar	88.2	.52
Wood alcohol	13.2	1.00
Calcium acetate	13.2	.17
Ammonium sulphate	8.8	.21
		$5.65

Gas, more than is needed to dry and coke the peat, and worth as fuel at least 25 per cent. of the value of the coke.

Figures derived from the manufacturer's agent in America for the Ziegler process, show that a 4-oven plant treats about 100 tons of air-dried peat each 24 hours, and from this amount the following quantities of by-products would be obtained:

900 pounds of ammonium sulphate,	$3.07	per 100 pounds.....	$ 27.63
1,320 pounds calcium acetate,	2.53	per 100 pounds.....	31.02
65 gallons methyl alcohol,	.70	per gallon.....	45.50
280 gallons light oils,	.07½	per gallon.....	21.00
95 gallons heavy oils,	.07½	per gallon.....	7.12
715 pounds paraffine,	.03¾	per pound.....	26.81
3,100 pounds creosote oil,	.02¼	per pound.....	66.75
440 pounds asphalt,	.005	per pound.....	2.20
			$231.03
Deducting 10 per cent. for sale expenses.....			23.03
Actual value of by-products.....			$208.00

In addition, 33 tons of peat coke would be obtained.

The total expenses per day, including wages and salaries, chemical supplies, cost of preparing the peat, interest and depreciation, and general incidental expenses, are figured at $308.50, so that the 33 tons of peat coke, the primary product, will cost $100.50, or $3.05 per ton.

If the plant is increased to three times the given capacity the quantity of by-products is increased by so much, while the total cost of production is not proportionately augmented, so that the sale of the by-products will nearly or quite pay all the expenses, leaving the peat coke as practically all profit.

The cost of such a plant is large, however, and estimates given for the smaller plant of four ovens make the first investment, including a working capital of $60,000, amount to $160,000; and while this is not excessive for a chemical plant, it is a large sum to venture, when a substance yet unknown and almost unthought of in this country is made the chief product sought. Besides the Ziegler coke plants, at least two others are in operation in Germany, the most recent of which is the Torf-Koks Geselschaft, Oldenburg, Germany, which, because somewhat simpler is said to be more easily run than the Ziegler plants, and more profitable.

The financial success of such a plant naturally depends upon the skill with which the technical work is carried on and upon the ability of the management to find a good and steady market for all of the by-products proposed, which it will be noted are all well known staples. In Ziegler's most improved plant the tar is converted directly into a lubricating material resembling

soap, which finds a ready sale to railroads and is more profitable than distilling off the oils, which have to meet the competition of the petroleum derivatives and could hardly be produced with profit in America.

The points that need special emphasis here are, that the quantity of chemical by-products to be obtained from the distillation of peat in coking retorts is so small that it is only possible to make their recovery pay when operations are skilfully planned, and carried on on a large scale under skilled technical and business management. If, however, these conditions are fulfilled, there seems no reason why peat should not be used for the purpose as successfully here as in Europe, after the value of the peat coke is recognized.

THE BY-PRODUCTS GAS-PRODUCER.

The producer-gas plant is a later invention than that for the production of charcoal or coke, but it was foreshadowed, like all great improvements, by early investigations into the problems of gas production. In the gas-producer making fuel or power gas, in theory at least, all of the carbon of the fuel is converted into permanent gases, so that nothing remains of it but ash. The gas-producer may be defined then as a furnace in which a portion of the fuel is entirely converted into carbon dioxide to transform the remainder into permanent gases, which still have the power to chemically unite with oxygen with the development of heat. In most types of gas-producers this is accomplished by using large quantities of fuel and limited amounts of air mixed with steam, so that combustion is complete only at the bottom or top of the thick fuel bed. After leaving the zone of complete combustion the gases pass into contact with the incandescent carbon of the fuel that has been heated from this zone, and thence through the mass of freshly added fuel from which the more volatile compounds are just being distilled. Carbon monoxide is formed by the contact of the incandescent carbon with the carbon-dioxide from the zone of complete combustion, and the steam that has been formed in or forced into the fire is decom-

posed with the liberation of hydrogen and the formation of carbon monoxide. Producer-gas then consists of carbon monoxide, hydrogen and a certain amount of nitrogen, together with small amounts of carbon dioxide which passes through the gas-producer without decomposition, or is formed at places where the temperature is too low to permit its decomposition into carbon monoxide. There are also present in producer-gas, tarry and gaseous hydrocarbons, dust and ammonia in varying amounts, according to the quality and kind of fuel used, the type of producer and the temperatures developed during gasification.

Gas-producers were first used to generate fuel gas for metallurgical and similar operations, and for such uses it was unnecessary to purify the gas to any extent before using it, but as the gas engine was developed, and it was found that the value of gases used in properly designed gas engines was disproportionately high for those with low calorific value, producer-gas was more and more used in them and it was found that purification of the gas was necessary, especially where the engine was attached directly to the gas-producer and often generated the gas by its own suction piston stroke as it was needed.

In the generally used types of gas-producers in which fuel rich in fixed carbon, like anthracite, coke and charcoal, are gasified, the gas is freed from dust, tar and other condensible matter by passing it through cooling and cleansing apparatus on its way to the gas engine. The cylindrical tower scrubber filled with coke or shavings, kept constantly wet by water spray and which is in effect a gas filter, is a commonly used type of purifier,

As the use of the gas-producer spread to other fuels, especially to bituminous coal and peat, the proportion of condensible gases given off was much greater than with anthracite or coke, and with them also in many cases that of the commercially valuable ammonia. With changes to these fuels, therefore, we have heard considerable of by-products recovery, by the addition of suitable apparatus to the gas-producer to fix in permanent form and save the combined nitrogen of the fuel which the heat converts into ammonia and drives off with the other gases.

The demand for ammonium compounds for agriculture, for chemical manufacture, and as sources of ammonia for refrigeration, has so greatly increased within the past few years that new sources of this valuable and comparatively costly substance are constantly being sought.

Its production as a by-product of fuel distillation is not a new thing, as is well known, for as long ago as 1889, Dr. Ludwig Mond in a presidential address before the English Society of Chemical Industry presented a statement, that experiments in distilling coal in a current of steam had given him almost twice as much ammonia as he had obtained by distilling the same coal in a current of air and steam. The studies of Mond eventually led to the development of the type of gas-producer bearing his name and primarily designed for the generation of producer-gas from bituminous coal, with the formation and recovery of the largest amount of ammonia permissible with the formation of producer-gas that would combine with oxygen.

A brief account of the construction and operation of this gas-producer may not be out of place here. The gas-producer proper is a vertical cylinder with double iron shell, and tapers out into a cone-shaped base which passes into a water-sealed ash-pit at the bottom.

The lower two thirds of the cylinder and the cone, or bosh, are lined with thin firebrick, while above the lining are the outlet pipes and the hopper for introducing fresh fuel, the latter being gas-tight.

The hopper opens downward into a wide cylinder reaching to the level of the fuel bed, with its mouth some distance below the opening of the outlet pipe. The latter is connected with a series of double iron tubes which serve as regenerators for pre-heating the air and steam used in the gas-producer and at the same time cool the gases passing through the inner one into the recovery plant. After leaving the regenerator the gas is forced into a tar extraction chamber and then to the acid tower, which is filled with brick checker work kept constantly wet by a fine spray of dilute sulphuric acid supplied at the top of the tower, while the gas enters at the bottom.

The ammonia in the gas in passing through the checkerwork in the tower is brought into close contact with the sulphuric acid and unites with it, and, in dilute solution, mixed with uncombined acid, flows out of the bottom of the tower into a properly placed tank, from which it is pumped again to the top of the tower. This process is repeated as usual in such methods until the mixed salt and acid solution reach a fixed degree of concentration for the salt, when a portion of the liquid is removed and more acid added, the part removed being pumped into concentrating tanks and treated.

The object of the prolongation of the fuel hopper into the fuel bed of the gas-producer is to secure the distillation of the water and tarry matter from the fuel as it sinks into the heated zone. As the distillates cannot find their way out through the hopper they are forced downward through the hot fuel and there decomposed into permanent gases. An essential of the process is that the fuel should not rise above a dull red heat, and this is secured by forcing into the fuel bed with the air a large amount of superheated steam; 2½ pounds of steam and 3 pounds of air at about 485° F. are furnished for each pound of fuel used, is the proportion given by Mond. Only about one sixth of the steam is decomposed, the rest being condensed in the scrubbers.

The avowed object of the use of the excess of superheated steam is to keep the temperature of the fuel bed so low that the combined nitrogen of the fuel will be converted into ammonia, and will not be again decomposed, as is the case when higher temperature than a dark red heat are used. The gas leaving the producer has a temperature of about 925°–930° F.

The Mond gas-producers were primarily designed for use of coal and for installations of large size, and but one has been erected in the United States, at Wyandotte, Michigan.

A yield of as much as 4 tons of ammonium sulphate from 125 tons of coal has been reported from English plants of this type, although the yield of the by-product must obviously be controlled by the percentage of combined nitrogen in the fuel used as well as the skill with which the gas-producer and recovery plants are operated.

The Mond gas-producer has been thus fully described because of the announcements made within the past two years of its modification and application to the use of peat by Dr. A. Frank, of Charlottenberg, Germany, and his associate, Dr. Caro. The statements made by these well-known technical chemists are to the effect that they have perfected a special form of gas-producer, using large amounts of steam in which peat with 40 per cent. moisture has been successfully converted into as good quality producer-gas as that made from coal, accompanied by the recovery of ammonia as ammonium sulphate, nearly up to the theoretical amount possible from the combined nitrogen shown by analysis to be present in the peat.

It is easy to show that the amount of ammonium sulphate that can be obtained from peat with a given percentage of combined nitrogen is 132/28 or 33/7 times the number of pounds of nitrogen found to be present; it is, therefore, easy to calculate the maximum amount obtainable under theoretical conditions from any sample of peat that has been properly analyzed, A short ton of peat, theoretically dry, with 1 per cent. of combined nitrogen, should yield 94 pounds of ammonium sulphate, with 2 per cent. nitrogen, 188 pounds, and with 3 per cent. nitrogen, 282 pounds; which at current prices of the product of about $60 per ton at the works makes it worth while to consider the possibility of its recovery, especially as the gas which has been freed from it is better for use in gas engines. It should also be stated that from 70,000 to 80,000 cubic feet of producer-gas to the ton may be generated from peat, and more than this has been reported; the calorific value of this gas is usually quite as high or even higher per cubic foot as that generated from coal in the same kind of gas-producer.

An electric horse-power per hour can be generated by the use of from 2 to 4 pounds of peat in the gas-producer, and for good peat and the right type of gas-producer the amount will be nearer the lower figure.

Actual tests of the Frank and Caro process, in Mond gas-producers in England, as described by the inventors, show from

65 to 70 per cent. of the theoretical amount of ammonium sulphate obtained from peat, with 1.62 per cent. of combined nitrogen, or 107 pounds to the ton of dry peat gasified. The gas from this test was used in part to run gas engines that had been running on producer-gas from bituminous coal, and it is reported that the man in charge of the engines could not tell when the peat gas was being supplied the engines. The peat used gave 48,000 cubic feet of producer-gas to the ton, with a calorific value of 152 B. t. u. per cubic foot. A part of this was used as fuel to generate the steam used in the gas-producer, and in evaporating the ammonium sulphate solution, but enough was left to generate in the producer-gas engines, 480 horse-power hours for each ton of water-free peat gasified. The cost of production per 100 tons of dry peat used is estimated at $125, including all charges, while the ammonium sulphate made in the by-products plant was worth, at the market price, $325, and the gas was free and reached the engines perfectly pure. The Frank and Caro process is not the only one that has been developed in Europe for the recovery of ammonium compounds in connection with producer-gas plants using peat for fuel. Dr. Ziegler has invented a special gas-producer for peat with a recovery plant that has been in successful operation for some years at Schelecken, Germany; on account of the small size of the gas-producer, however, the recovery plant failed to be a commercial success. Crossley Brothers, Ltd., English makers of gas engines and gas-producers have also placed a gas-producer and recovery plant for peat fuel on the market.

From this brief discussion it is apparent:

1. That peat is considered a good source of producer-gas for fuel and power uses in Europe, where the use of gas-producers and gas engines is farther advanced than in the United States, in which country no manufacturer has yet advertised a gas-producer that he will guarantee to gasify peat. Some 500 gas-producer plants are now in use in the United States, however, in which 57 per cent. of the power obtained is from bituminous coal or lignites

2. The recovery of by-products, and particularly of ammonium sulphate from gas-producers using peat for fuel, is not only possible theoretically, but is commercially so practicable that large plants using the Frank and Caro processes are now reported to be in operation or in the course of development in England, in northwestern Germany, and at Pontedera, Italy; the Ziegler plant at Schclecken was completely successful from the point of view of the engineer, since it did the work for which it was designed, economically and well.

3. That for small peat gas-producer plants for generating electric or other forms of power, the quantity of ammonium sulphate that can be secured even from peat rich in combined nitrogen by the best processes, while technically entirely possible, would probably not prove commercially successful, since the cost of maintaining a small recovery plant is large when compared with the margin of profit. This is due, of course, to the fact that the same technical superintendent and high-priced workmen are needed in small as in large plants. On the other hand peat that is rich in nitrogen, and some black kinds run as high as 3 per cent., when gasified under carefully regulated conditions in a properly designed gas-producer, will yield a considerable amount of ammonium sulphate; the exact quantity that must be recovered to allow for safe investment is a matter of calculation and of actual experiment under American conditions. One of the European plants in process of construction is planned to develop when complete at least 5,000 electric horse-power, and turn out besides some 3,000 tons of ammonium sulphate each year, using for these purposes 65,000 tons of dry peat. In this large plant about two pounds of peat, with a thermal value of 8,600 B. t. u. per pound, is allowed in the gas-producer per commercial horse-power per hour, which is amply confirmed by independent and reliable figures. No statement is reported, however, of the number of heat units that must be used up in generating steam for the gas-producer, etc., although it is known that the plant is well planned to conserve heat.

At $2 per short ton, which is a high price for peat fuel at

the bog, the unit of power would cost two tenths of a cent, or at this price a horse-power per ten-hour day can be had for two cents.

From this brief discussion it is evident that power and fuel gas production from peat on a commercial basis is an accomplished fact in Europe, and that as the installations for the purpose have become of sufficient size, the recovery of chemical by-products, and especially of ammonium sulphate, has also been technically established; whether or not it is commercially possible in large plants will soon be demonstrated.

The process recently worked out and described by Dr. Herman Woltereck differs from all of those that have been mentioned, in that chemical products secured by the complete combustion of wet peat at low temperature are the only objects of the entire treatment.

The fundamental proposition of Woltereck is that the nitrogen that appears in the ammonia that he secures is, in part at least, derived directly from the air, so that he practically makes a synthetic ammonia by fixing atmospheric nitrogen.

This claim is founded on a long series of carefully planned laboratory experiments, apparently fully worked out and reported before several scientific societies of highest standing; among others, the British Association, in 1908. The important part of the statement, from the present point of view, is that when wet peat is burned at a temperature sufficient to keep the fire going in a specially designed furnace, some of the nitrogen of the moist air forced into the combustion zone induced by the oxidation of the carbon unites with the hydrogen of the organic matter that is being decomposed and forms ammonia. These results were announced in full only after experimental work covering eight years or more, in which many other substances were tested and various temperatures and length of exposure of the gases to the heat were tried, the wet peat being found to be the cheapest and most productive material. In addition to the ammonia, as the result of the wet combustion, tar, tar-water and other distillates are obtained in abundance, and from these

it is proposed to manufacture acetic acid, as calcium acetate and paraffine. No combustible gases can be produced, since it is aimed always to keep the temperature of all the fuel bed below that at which water is decomposed by incandescent carbon (550° C.) and at which carbon dioxide is reduced to carbon monoxid (600° C.). The reason for maintaining these low temperatures is that in experimental work it was found that the largest percentage of ammonia was obtained, under the various conditions tested, at temperatures from 300° to 350° C., but under those necessarily maintained in the larger operations it was found that the best range of temperature was from 400° to 500° C., and this is maintained as closely as possible.

After an experimental plant had been erected and tested thoroughly in every way, the erection of one with a capacity of 5,000 tons of ammonium sulphate a year was begun in 1904, near Carnlough, County Antrim, Ireland, and it was announced last fall that all of the numerous technical difficulties had been conquered and that operations would begin this spring (1909).

The actual operation of the plant is described in a pamphlet issued by the Chemicals Proprietary Company, Limited, as follows:

After the peat has been dug and conveyed to the works by an aerial conveyor it is automatically fed into hoppers worked with compressed air and quickly dropped into the furnaces. Here it is subjected to moist combustion by means of a blast of air charged with steam at a carefully regulated temperature of 400° to 500° C. (750° to 950° F.). The resulting gases contain paraffin tars, acetic acid and ammonia. The tars are removed by the Woltereck scrubber (a bath of heavy petroleum oil heated to 300° C.) without condensation and consequent loss of ammonia. The acetic acid is next absorbed in the alkali tower, where the gases meet a hot solution of soda or milk of lime and combine with it to form acetate of soda or lime, which may afterwards be treated for the recovery of acetic acid or the production of acetone.

The gases pass from the alkali tower to the acid towers, where

they meet a stream of hot dilute sulphuric acid, which combines with the ammonia to form sulphate of ammonia, the chief object of the process. After the acid is completely neutralized, the solution of ammonium sulphate is drawn off to the crystallizing vats, concentrated and allowed to crystallize, and after centrifuging to remove adhering liquor is ready for shipment, The paraffine tar is drawn off from the scrubber, when a sample of the oil therein solidifies on cooling. It is then subjected to distillation to remove the lighter oils and a crude paraffin wax worth $25.00 per ton remains without further purification.

This, of course, is the best presentation that can be made of the process as a whole, and gives no details of the many mechanical and other difficulties that have been met in building the furnaces, the grates, the tar scrubber, and the recovery plants to have them all work together. The fact that the plant has been more than four years in process of construction is evidence of this.

Woltereck states in his paper read before the British Association in December, 1908, that the average amount of ammonium sulphate obtained by the tests made at the experimental plant was nearly 7.5 per cent. of the peat calculated as theoretically dry, and yields as high as 13.9 per cent. were obtained. If these figures are reduced it will be seen that the average yield of ammonium sulphate was 150 pounds per short ton and the maximum 278 pounds per ton. Peat with 2 per cent. combined nitrogen, theoretically should yield 188 pounds of ammonium sulphate per ton of dry peat, of which the amount given is about 80 per cent. The average nitrogen content of the peat used in the experiments is not given, and 2 per cent. of nitrogen is very high for European peat, as is also an 80 per cent. recovery. The maximum yield of 13.9 per cent. reduces to 278 pounds per short ton, or very nearly the entire amount theoretically obtainable from peat with 3 per cent. combined nitrogen. We must assume that the peat was exceptionally rich in nitrogen and that the percentage of recovery is unusually high in this case, unless the alternative is accepted that the process does as the

inventor claims, produce synthetic ammonia from nitrogen from the air.

From the commercial and administrative points of view where are many matters yet needing consideration. Woltereck claims a minimum production of 5 tons of ammonium sulphate per 100 tons of theoretically dry peat substance treated, which is conservative enough when 7.5 per cent. is the average of experimental production on a large scale. The peat is used, however, with at least 75 per cent. of water, and may be used with more; this means the digging, handling, and treating of at least four short tons of wet peat for each ton of dry matter used, besides the unknown quantity, or its equivalent in heat units, that must be provided to furnish the power needed and the great quantities of superheated steam used in the furnaces, and in the recovery plant. There are few bogs of such size in the United States that would stand this draft for many years. The matter of labor costs per unit of production and that of the heat balance, as in all chemical manufacturing plants where dilute solutions must be concentrated and purified, will have to be carefully considered before the financial balance will be favorable.

The inventor has evidently satisfied his financial supporters that these matters can be successfully met, but no available published account gives the fuel estimate in detail.

The claims for this process as announced by its inventor are:

1. It gives a much larger recovery of ammonium sulphate than Frank and Caro's.

2. It permits the successful use of peat with from 75 to 80 per cent. of water, which is practically as it is dug.

3. It is independent of all other industries, so that the plant can be operated on its own merits, and not on the basis of other and entirely foreign business, as is the case with by-products plants, which must be closed when the power plant is not operated.

4. Acetic acid and paraffin enough can be recovered to meet all expenses of digging the peat and burning it, so that the ammonium sulphate worth about $60.00 per ton will be practically all clear profit.

This process has been criticised somewhat unfavorably in the late numbers of the *Journal of the German Peat Society*, "Mitteilungen Verein zur Foerderung der Moor-Kultur in Deutschen Reiche," by Dr. Caro, but details cannot be entered into here.

It will be impossible to do more than mention Bamme's peat-coking and by-products plant which is similar to Zeigler's in many particulars, and is established at Elizabethfehn, Germany. A process has been patented in England, by Hoering and Mjoen, using the water evaporated from moist peat during combustion so that it reacts to increase the amount of ammonia and tar that may be recovered. Another process is one patented by Ireland and Sugden, which prepares ammonia from nitrogen of the air by conducting air and steam through peat heated to from 300° to 500° C. (575°–595° F.), in upright iron retorts covered with firebrick. No report upon these processes seems to have been published, and it is assumed they have not yet attracted capital enough to be tested in a commercial scale.

From time to time reports are received from Europe of commercial production of ethyl alcohol from peat. These processes are apparently all based on the conversion of the cellulose of poorly decomposed fibrous peat into grape sugar by digestion with dilute sulphuric acid. After neutralization with lime the sugar solution is concentrated, fermented and the alcohol resulting obtained by distillation.

In concentrating the solution substances poisonous to the yeasts are concentrated with the sugar, so that fermentation does not take place if the sugar solution is strengthened too much. Special yeasts resistant to these poisons have been reported from Denmark and France, but the plants established to utilize them have not been reported upon recently. Not more than 12 per cent. of the peat substance is converted to sugar, and of this one half is arabinose, which does not ferment. It is apparent that there are many better materials than peat going to waste in this country that might be used for the production of alcohol.

Peat is also proposed as a means of intensive production of nitrates on the following principle, developed by Müntz and

Lainé. A culture bed of peat, watered with a dilute solution 0.75 per cent. of ammonium sulphate, and innoculated with nitrifying organisms and kept at a temperature of 38° C., yields, after a time, nitrates to the extent of 0.82 per cent. This quantity can be increased to over 4 per cent. by adding more of the ammonium sulphate to the solution and again subjecting it to the nitrifying action, the operation being repeated five times. Ammonium sulphate can be obtained from the peat by distillation, after it will no longer yield nitrates, and the tars and gas obtained at the same time would furnish heat enough to carry on the necessary operations of a plant. This process has not been embodied in a commercial plant, but the feasibility of so doing may well be considered when a plant involving the development and utilization of 100,000 horse-power water rights is established to produce "cyanamide" by the action of nitrogen on calcium carbide at high temperatures, a process enormously wasteful of electrically-generated heat energy.

The production of tanning materials from peat has also been carried on in an experimental way, as there is a certain percentage of tannin and tannic acid present which may be obtained by proper chemical treatment. Doubtless peat of the proper composition would yield a sufficient percentage of matter that would be rich in tannic acid and other tanning materials; it is probable that peat from woody plants would be best for this purpose.

From what has been said it is apparent that the processes outlined all have commercial possibilities in this country, if enough capital is available for the construction and maintenance of a plant through the stage of development. Where a market can be had, or is waiting for peat coke, as in the iron-bearing regions of Michigan, Wisconsin, and Minnesota, this should be the primary product, with by-products recovery so far as markets could be found for the material that could be made from the condensible gases. When power can be readily disposed of, producer-gas for the generation of electricity is clearly indicated as a means of most successfully using peat deposits, and if the

power plant is a large one, by-products recovery will reduce the operating expenses if the heat balance is carefully watched and a proper type of gas-producer used, so that the largest possible amount of the valuable ammonia is recovered, as it seems demonstrated that such recovery may be carried on profitably in properly designed large installations.

The Woltereck process is not a by-products or peat gasifying process, but a method of making ammonia by burning wet peat under such conditions that no combustible gas or product used for fuel is obtained; that is, it is chemical manufacturing, pure and simple.

The other processes mentioned are not yet developed on a commercial scale, but may have future possibilities.

In conclusion, it should be said that it is desirable to have some of the commercially promising processes of chemical manufacture outlined here tried under American conditions, so that it may be demonstrated that it is as profitable to use them here as in Europe.

DISCUSSION

This department has been established by the editors in order to afford to those interested in questions relating to economic geology an opportunity for informal discussion. Contributions are cordially invited either in the form of discussion of more formal papers appearing in earlier numbers or bearing upon matters not previously treated. Letters should be directed to the Editor, Sheffield Scientific School of Yale University, New Haven, Conn. The full name of the author should be attached to all communications.

ABSENCE OF SECONDARY COPPER-SULPHIDE ENRICHMENT IN CALCITE GANGUES.

Sir:—In comparing the gossans of copper deposits with deeper development I have, of late years, paid particular attention to the composition of the gangue in its influence on secondary enrichment. Usually I have found that secondary copper-sulphide enrichment is quite or almost lacking when the gangue contains much calcite.

This condition might be explained in the following way: In the oxidizing zone copper sulphides oxidize to copper sulphates which, being soluble, tend to percolate down to water level, there to be precipitated as secondary sulphides. The copper sulphate may come in contact with a precipitant and be decomposed before reaching water level. Organic matter may cause metallic copper to be precipitated, and calcite or other carbonates may cause copper carbonates to be precipitated. As copper carbonates are but slightly soluble under ordinary conditions the further descent of copper towards water level is checked.

If there is more than sufficient copper to replace the calcite, or to form an insulating coating on it or on the calcareous walls to the channels of descending solutions, then any excess copper sulphate will be free to descend and produce sulphide enrichment.

Where there is no calcite or other carbonates in the original gangue a small amount of copper carbonates may be formed

from carbonated surface waters associated with decaying vegetation. In my experience copper carbonates formed in this way are of slight extent.

Where the gangue contains so much calcite that it surrounds the original sulphide minerals, the copper sulphate resulting from oxidation has no chance to migrate and copper carbonates are formed around the original sulphide kernel.

Where there is considerable calcite in the gangue there is sometimes a secondary enrichment of carbonates, making the oxidized zone richer in copper than the sulphides below.

Sometimes the gangue may contain an excess of calcite and still there is secondary chalcocite below. In these cases I have noticed usually that the channels of descending solutions have been coated with copper carbonates which insulate the copper sulphate from further precipitation by calcite, thus permitting it to descend to water level.

In some few cases in my experience chalcocite appears to have been formed under conditions in entire disagreement with this reasoning. Two explanations have been suggested for this. One is that, under certain conditions, copper carbonates may be soluble and are carried down the same as sulphate. The other is that chalcocite is sometimes a primary mineral deposited from alkaline solutions.

Consideration of this matter is of decided practical utility. My experience has been such that now, in the examination of a copper prospect, if I find much calcite in the gossan, I seldom advise sinking on it with the expectation of finding much secondary sulphide enrichment. Many deposits in limestone and on limestone contacts come within this class; also some deposits in basic igneous rocks. The insulation factor previously mentioned is always considered.

This presentation carries less weight than it would if it were accompanied by particular illustrations and data from known ore deposits, but I have not thought fit to go into these details at this time. My object here has been to bring the subject to the attention of those competent to discuss it.

Some of the chemistry of the above reasoning is capable of experimental proof. I have done nothing along this line.

Incidentally this communication shows the need of clearer distinctions in the meaning of "Primary" and "Secondary" enrichments.

DARSIE C. BARD.

Sir:—No one who writes for publication should be supersensitive to criticism, but he may reasonably ask that his critic take into account the clearly stated purpose and plan of the work criticised. The tenor of Professor Lawson's review of a hand-book for field geologists in the November number of ECONOMIC GEOLOGY clearly indicates that he has failed in this fundamental particular. The circumstances under which the book was prepared, as stated in the preface, have apparently been overlooked.

Instruction in methods of making and recording observations in the field is given in a few of the better equipped geological departments of the larger universities, but a majority of those who take up geology as a profession, particularly on the economic side, do not have the benefit of such instruction. So far as am aware it is not contained in any of the text-books and the beginner must learn through experience what are the best methods. To place the experience of others at his disposal is the main purpose of the hand-book. It is not even intended to be a "compendium" and many methods and instruments are not mentioned because they are considered less efficient than those described or are applicable only to very special and exceptional cases.

The subject of geological nomenclature is undoubtedly a painful one, and it will remain so until geologists generally are willing to restrain their ambition to see their own particular labels applied to the rocks they happen to discuss. Since the Federal Survey is making the most important serious effort to bring order out of existing chaos, it was thought a brief statement of the procedure adopted would be of sufficient interest to geologists to warrant incorporation in the hand-book. There was no intention

of discussing the criteria for classifying any particular set of beds or determining in which of the categories they should be placed. These criteria are fully discussed in the Twenty-fourth Annual Report to which reference is made.

The instructions for special investigations undoubtedly suffer from condensation, but they are not intended to replace text-books or systematic instruction. It would manifestly be entirely beyond their scope to cite illustrations and examples or to attempt a selection from the great mass of geologic facts on which the science is based. Their main purpose is to indicate the significance of some of the more important points which the geologist should have in mind in his field investigations. Criticism of these instructions should be made in view of this clearly stated purpose.

The specific criticisms of this portion of the hand-book are somewhat unfortunately chosen. For example, objection is made to the statement that one of the characteristics of a peneplain is "absence of undrained areas." "The only undissected peneplain which the reviewer has had the good fortune to behold" is presumably the Canadian protaxis, and the character of its surface is due to a physiographic incident wholly independent of and subsequent to the plantation. The occurrence and location of monadnocks and the "lack of interruption of peneplain surface on rocks of very different resistance" are both important considerations in physiographic study, and the latter condition is by no means confined to wave cut or stream cut terraces as the reviewer states.

It is presumed that anyone who makes use of the hand-book will be endowed with a fair degree of intelligence and when he is instructed in the field study of igneous rocks to "observe mineral composition and texture carefully" he will not attempt the impossible, but will confine his observations to those features which are within his power. It is conceivable that a person wholly unfamiliar with igneous rocks might be confused by this statement, but anyone else would at once recognize the implied limitations.

It migh be inferred from the review that cross-bedding is referred exclusively to wave action. The statement in the hand-

book is as follows: "Cross-bedding is indicative of wave action or great river currents and must be studied in the light of other characteristics of the strata."

In the study of placer deposits special emphasis is placed on the necessity for observing character of both overburden and pay streak—size, shape and composition of constituent materials and whether loose or cemented, with nature of cement. The importance of studying "the distribution of the mineralization in the bed rock from which the placer deposits have been derived" was purposely emphasized, since this in many cases is a matter of fundamental importance. As in many of the other instructions contained in the book, it was not considered necessary here to tell the field geologist not to do things which the nature of the case make it impossible to do.

The fields of the economic geologist and the mining engineer are not sharply defined. They necessarily overlap and the schedules are prepared in the recognition of this fact. It is quite true that they provide for the collection of information relating to mining methods and to character and disposition of product. An economic report usually includes these subjects and they are the ones on which the geologist is most likely to find his notes incomplete and unsystematic. It was considered desirable to have the schedules fairly comprehensive so that an observer might select and use the portions which meet his particular needs rather than to confine them to any restricted class of observers.

C. W. HAYES.

THEORIES OF OIL AND GAS ACCUMULATION.

DISCUSSION OF A PAPER BY M. J. MUNN.

Sir:—It is not my purpose to contribute any discussion from field experiences of Mr. Munn's very valuable and suggestive paper at this time. This is not because there is not needed an accumulation of facts bearing on the relation of oil and water in wells, but because I believe we need very much more, some experimental work. We field geologists have not the facilities nor the technique to carry on certain crucial experiments that seem to me of the utmost importance.

Mr. Munn has told us that our low gradients in the principal oil fields cannot dissociate oil and water laterally, but it would be more valuable if some geological physicist would tell us *just what* gradient will act and to what extent this varies with the oil and rock experimented upon. We are told that water will carry oil with it and that the opposition of such currents will accumulate it in economically important concentration. But do we *know* whether this oil may not be carried along in such a diffuse condition that such a region of opposing currents would have too small a load to effect an important concentration? Yet it would be possible to discover how water acts in moving through oil shales.

It would even be of help to know the relative rapidity with which oil and salt water in a mixture would be forced by applied pressure into sandstones of various porosities. We are told that the battle for capillary space between the water and the oil will go on until the water ultimately forces the oil into the more porous portion of the rock where capillary attraction is weakest. But since this is capable of experimentation we may well reserve judgment. Of course unusual apparatus would be necessary in such an experiment and rather long cores of stone carefully selected, but that merely necessitates that the work must be done in the Government laboratories or otherwise assisted.

The problem of oil accumulation must reach the quantitative stage of its investigation before the hydraulic theory can be evaluated. The work of Dr. David T. Day is of great importance and is thoroughly appreciated, but we need more extended work more specifically touching oil accumulation.

ROSWELL H. JOHNSON.

A BIBLIOGRAPHY OF THE DIAMOND FIELDS OF SOUTH AFRICA: ALEXIS. A. JULIEN.

Sir:—I have been collecting references on the Geological Occurrences of Diamonds in a desultory way for the past few years, and welcome the very complete Bibliography published in your August number. I find, however, that I have a few references

not included by Mr. Julien, and although I am unable at this distance from a library to check them, I offer them for what they are worth.

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J. ALLAN THOMSON.

KALGOORLIE,
November 27, 1909

[1] ? exact title.

REVIEWS

Report on the Iron Ore Deposits of Nova Scotia, Part I. By J. E. WOODMAN. Department of Mines, Mines Branch, Ottawa, Canada, 1909. Pp. 226.

This report is one of a series of monographic studies on the ores of Canada being prepared by the Mines Branch of the Department of Mines of Canada.

The Nova Scotian iron ores are widely distributed over the province in pre-Cambrian, Paleozoic, Triassic, and recent terranes, but the ores have been, or are likely to be, of commercial importance only in two localities, the Nictaux-Torbrook area in Annapolis County, where are bedded hematites of the Clinton type in the Silurian, and in the Londonderry area in Colchester County, where are irregular carbonate and limonite veins in the Devonian.

In the Nictaux-Torbrook area two beds are thought to be of probably commercial importance. Each of them has been traced for nearly three miles along the strike. The thickness does not run above five feet three inches and is usually less. The underground extension of these veins is thought to be complexly folded and to afford possible basins for thicker concentrations. The ore is low grade, ranging up to 53 per cent. in iron, usually less, and in phosphorus from .7 to 1.05 per cent. Small shipments, about 130,000 tons, have been made to the Londonderry furnaces for mixture with the Londonderry ores, but since 1906 there has been no shipment.

The Londonderry ores are veins of carbonate of iron, magnesia and calcium, oxidized at the surface to limonite, in Devonian sediments. In early days the workings were entirely in the surface limonites. They now include much carbonate. The limonite is said to average 40.72 per cent. in iron, the carbonate 16.63 per cent iron. Both are lower in phosphorus than the ores of the Nictaux-Torbrook area. The principal group of mines has produced over two million tons of ore.

The author concludes in general that the province of Nova Scotia shows no probability of developing an iron industry from its own ores that will enable it to compete very extensively with the American and Ontario products in their own fields. Its success must result from its comparative isolation, which diminishes the intensity of competition.

It has, so far as now known, no deposits showing such size, quality and low cost of treatment as to compare favorably with Bell Island on the one hand, or the Lake Superior ores, both Canadian and American, on the other. But there does appear to be a possibility that Nova Scotia may yet be able, with her own ores, to supply eastern Canadian demands. Unless some body of high grade specular ore or magnetite be found, there are no high grade Bessemer deposits in the province.

The descriptions of individual deposits and prospects are carefully and well done. The impartial manner in which the author discusses the probable commercial availability or non-availability of deposits is to be commended. The reader misses any general table of production showing the relative importance of the districts in the past and clearly discriminating the districts which have not produced ore. This makes it difficult to determine without reading all the detailed descriptions the relative importance of the deposits based on actual performance. Also the reader meets some difficulty in obtaining readily the essential general characteristics of a given deposit, because the ores of the province are treated as a whole from geographic, geologic, mineralogic and chemical standpoints, making it necessary to refer to several sections to find out about one of the deposits. This deficiency is of course supplied by the detailed chapters. The writer intimates that a second volume will be forthcoming, in which these features will be considered. The report is accompanied by a general map showing the distribution of the ores of the province and by detailed maps of the several areas studied in detail.

C. K. LEITH.

The Geology and Mineral Resources of New Brunswick. By R. W. ELLS. Department of Mines, Geological Survey Branch, Ottawa, Canada, 1907. Pp. 135.

New Brunswick has mined small quantities of iron ore in the past, but produces none now. A brief summary is made of the various localities in which ores are known. At present the largest known area of iron ore yet found in the province is located near the mouth of the Nipisiguit river, about 22 miles from the town of Bathurst, and near the junction of a small stream known as Austin brook, about one mile above the head of the Grand falls. The rocks are altered slates, in part schistose, cut by masses of green diabase and the ore is a magnetite occuring in a large mass extending back from the river to the north for about two miles, with an exposed width in places of thirty to forty feet. Quite recently another body of similar ore was found in the vicinity. The quantity of ore in the whole deposit is very large.

The author concludes that there is little now to be said in favor of iron mining in New Brunswick, but that the new discoveries near Bathurst and vicinity afford a probably profitable field of investigation, if the cost of transport is not excessive.

C. K. LEITH.

Report on the Iron Ore Deposits along the Ottawa (Quebec side) and Gatineau Rivers. By FRITZ CIRKEL. Department of Mines, Mines Branch, Ottawa, Canada, 1909. Pp. 147.

Iron mining has not been successful in this area, but of the several known ore deposits, two are thought to have some promise for the future, those at Bristol and Hull. The ore of the Bristol Mine is in lens-shaped beds and pockets between walls of gneiss and hornblendic schist. It is high in sulphur, low in phosphorus, and locally shows much intermixture with silicates and wall rock. The grade is said to be good, but the specific figures given are not related to specific widths of ore bands. The Bristol Mine has produced about 12,000 tons.

At Hull there is magnetite with some hematite in vein and shoot-like lenses in limestone. Here the ore also contains an abundance of silicates and more pyrite than is desirable. Phosphorus is low. The ore is said to contain all the way from 53 to 67 per cent. of metallic iron, "if some attention is paid to the separation of the crude ore from the accompanying gangue." There is great variation in silica, "due to the fact that the iron ore grades into ferruginous hornblende." The author remarks concerning the map that the "areas containing iron ores of present commercial value have been shaded. It must be said, however, that the ore deposits do not occupy all the areas shaded, but each of the latter contains some iron ore of more or less economic importance."

The origin of the ores is not discussed.

The author concludes that there may be considerable development of the iron industry, especially in the Hull and Bristol localities, in view of the possibility of applying modern methods of concentration of the ores and electric smelting, and considerable space is given to a discussion of the possibilities of application of these processes.

The report calls for a word of friendly criticism, a criticism which may apply to another one of this series of reports on iron ores, that of Professor Hille on the Port Arthur deposits.[1] The facts, as faithfully portrayed in the detailed descriptions, indicate that in all of these dis-

[1] "Report on the Examination of Some Iron Ore Deposits in the Districts of Thunder Bay and Rainy River, Province of Ontario." By F. Hille. Department of Mines, Mines Branch, Ottawa, Canada, 1908. Pp. 65. Reviewed in ECON. GEOL., Vol. IV., 1909, pp. 575–577.

tricts iron ores, while abundantly present in lean, scattered deposits, are in few, if any, places sufficiently rich, large, and free from deleterious constituents to meet present commercial demands in any considerable amounts, and that so far as they have been mined in the past, it has been intermittently and on a small scale. However, in the general discussions so much emphasis is placed on possibilities of future development of these deposits by means of concentration or electric smelting or other processes, that the indiscriminating reader is likely to get the impression that the deposits described are demonstrated to afford large and immediately available sources of supply for the development of a considerable iron ore industry. The reviewer fully believes that changing commercial conditions and methods may ultimately bring into the market many ores which are not now available, but regards it as undue optimism to predict the probable immediate availability of this or that deposit on the basis of such changes of methods and conditions as are described. So many factors, not easily measurable, enter into the problem that it is next to impossible for anyone to speak with certainty as to the coming availability of certain deposits. Even if new processes do develop as hoped, and make lower grade ores available, it is to be remembered that such ores are widespread, and it is still possible that some may remain undeveloped.

C. K. LEITH.

Elements of Mineralogy, Crystallography and Blowpipe Analysis from a Practical Standpoint. By ALFRED J. MOSES, E.M., Ph.D., and CHARLES LATHROP PARSONS, B.S. Fourth edition. 8vo, 448 pp., with 583 figures. New York, D. Van Nostrand & Co., 1909.

The fourth edition of Moses and Parsons's text-book of mineralogy differs in no respect from the third edition in plan. The introductory chapter, which deals with the general principles of crystallography, has been rewritten and amplified, and some of the comprehensive statements prefixed to the chapters dealing with the different groups of minerals have been added to. The advance of the mineral industry in the United States since 1904, the time of the appearance of the third edition, has, however, been so great as to necessitate a complete revision of the figures dealing with mineral statistics. These are now brought up nearly to date (1907), thus giving the volume the character of a brief summary of the mineral production of the country.

From a teacher's point of view the work still remains the best book in mineralogy published in America.

W. S. BAYLEY.

Iron Ores, Salt and Sandstones. By G. P. GRIMSLEY. West Virginia Geological Survey. Vol. IV., 1909, 603 pp., 24 pls., maps.

West Virginia has a past and a future history as a producer of iron ore. No ores are mined at present, but the estimated available future supply is about 140,000,000 tons of low grade Clinton hematites and Oriskany brown ores. The gradual increase in the production of steel by the open hearth process, the close proximity of the ores to flux, fuel, and smelters, and the decline in the grade of the lake ores are expected to make future production possible. The following is an average of 70 analyses of West Virginia ores:

Iron	43.86
Silica	19.48
Manganese	.328
Phosphorus	.560
Sulphur	.031
Lime oxide	.620

The well-known theories of the direct precipitation of the Clinton hematites from sea-water, and of the genesis of the brown ores by limestone replacement are accepted. No new arguments are presented in support of these views.

West Virginia ranks ninth in the union as a salt producer. The existence of the industry depends at present upon the valuable by-products, bromine and calcium chloride. Special attention is called to the use of calcium chloride in preventing dust on public highways.

West Virginia has undeveloped resources in building stone, whose quality is equal to the product shipped in from other states. This conclusion is based on an investigation of the stones of the Monongahela, Dunkard, Conemaugh, Alleghany, and Potsville series.

Statistical and geologic data are imperfectly correlated. The iron ores are discussed by counties, so that the reader has difficulty in gaining a perspective of the geographic and geologic relations of the ores for the state as a whole. The maps show in a crude way the distribution of the iron formations and iron prospects for the respective counties. These shortcomings in arrangement and presentation may lessen the value of a report, one of whose aims is to interest the public in certain undeveloped resources of the state.

EDWARD STEIDTMANN.

Geology of the Disseminated Lead Deposits of St. Francois and Washington Counties. By ERNEST ROBERTSON BUCKLEY, Ph.D., Missouri Bureau of Geology and Mines, Vol. IX., Parts I. and II. 250 pp., with 121 plates and 10 figures in the text. Jefferson City, [1909].

Of the two parts of this report, the first contains the text and 39 of the plates; the second consists entirely of plates. Of the text 87 pages are devoted to the general geology of the region, 116 pages to descriptions of individual mines, 32 pages to the genesis of the ores, and 10 pages to a description of the barite deposits of the area studied.

As the beds lie nearly in their original positions, undisturbed by notable folding, faulting or igneous intrusions, the section on the general geology consists mainly of good detailed descriptions of the character of the successive formations from the Lamotte sandstone to the Potosi limestone, statements of the carefully measured thickness of these, and much briefer characterization of the formations younger than the Potosi. Numerous columnar sections are given, but many of them convey singularly little information, being either unaccompanied by descriptions or so loosely tied to the verbal descriptions placed alongside of them that it is difficult for the reader to find correspondence between the two (see p. 31). An unconformity is described between the Lamotte and Bonneterre. The disseminated lead ores are all in the Bonneterre.

The beds are cut by many faults of normal type and small throw. Two well-defined systems are recognized, one striking northwest and the other northeast. These fault-planes have been important factors in directing and controlling the deposition of the galena and have been traced out by Dr. Buckley with skill and patience, this work constituting an important advance in our knowledge of the deposits.

The part of the report dealing with the ore deposits is, as already noted, made up chiefly of mine descriptions. The work appears to have been carefully done and the descriptions are full and good. Nevertheless, the treatment of the ore deposits is rather disappointing, due largely to the mode of presentation of the abundant material accumulated during the five years that the investigation was in progress. Detailed descriptions of mines are of interest to owners and to those studying some mine on the ground. It is asking too much of the ordinary reader, however, to expect him to peruse with interest description after description of this and that mine, all much alike and containing countless minute observations on joints, faults, brecciation and underground water. He has a right to ask that an author digest his mass of observations and that he present the essentials in proper readable form with reference to their relative importance in a general

discussion of the subject. The mode of occurrence of the ores in the different mines is more nearly identical than in most districts and it should not have been difficult for Dr. Buckley to present in a single interesting chapter the really significant facts observed underground, unencumbered by purely local detail and accompanied by some hint to his readers of the relative weight to be attached to these observations in the development of an hypothesis of genesis. The detailed descriptions of mines could then take their proper place as a sort of appendix to be referred to when necessary but not to be read through as part of the systematic exposition of a well-worked-out subject. Unfortunately there is no such chapter, and whoever desires to know the essential characteristics of the ore deposits and the main facts upon which the scheme of genesis has been constructed, must work them out as best he can from uninteresting accounts of single mines.

Dr. Buckley frankly states in his introduction that the hypothesis offered in explanation of the origin of the ore deposits is not in any way original. His work, accordingly, apart from such local utility it may possess, is to be judged broadly as a confirmation and amplification of views already advanced, especially those of Winslow. In treating deposits previously subjected to considerable study by others and not of great structural or mineralogical interest he labored under conditions that it is well to appreciate. It was almost a foregone conclusion from the outset that anyone taking up the study of these ores would not develop anything startlingly new as regards their genesis. All the more regrettable is it, therefore, that Dr. Buckley has not, in the light of his careful study, summed up, as few are equally able to do, the salient features of these deposits and marshalled in telling logical form the facts upon which his conclusions are based. These facts are all recorded in his book but are so ineffectively arranged and so interspersed with tedious detail that their connection with his conclusions, instead of being patent, is obscure. It is but fair to say, however, that Dr. Buckley, as the reviewer knows from personal conversation with him, plans the publication of such a summary in another place.

The ultimate source of the ores is held to be the pre-Cambrian igneous rocks. The lead originally deposited with the Cambrian and later sediments has in the course of the oxidation and erosion of these been concentrated by generally descending underground waters into the bodies now found in the Bonneterre dolomite, the locus of deposition being determined by joints, bedding planes and cavities in the rocks and by the mingling of oxidizing solutions with others in part of reducing character. There appears to be no essential difference between the views of Winslow and Buckley as regards the processes of genesis

of these ores and the conclusions of two workers may be taken as best according with all the facts at present known. Dr. Buckley's special contributions toward establishing these conclusions are the recognition of the fault-zones and joints in the lower part of the Bonneterre formation, the relation of the removal of the Davis shale to the circulation of the ore-bearing solutions, and the tracing of the historical development of the ore deposits.

Many of the illustrations including the maps and carefully drawn sections, are significant and useful, but this cannot be said for all; fully half might have been omitted without detracting from the value of the report. Many of the plates are of the awkward folding type and consist of plats or diagrams that might have been reduced to text figures and placed where they could be more readily consulted. There are several plates showing thin sections of ores as seen through the microscope but the magnification is not stated.

Dr. Buckley writes vigorously and generally with clearness, but there are occasional obscurities, as in the discussion of fault movements at the head of page 81, and there is perhaps an excessive use of the first person singular in places where a simple impersonal statement of fact would be more effective (pp. 191 and 192, for example).

The proof-reading, for which the author perhaps is not responsible, is inexcusably slipshod, and there is scarcely a page not disfigured by typographical errors.

F. L. RANSOME.

Igneous Rocks: Composition, Texture and Classification. By JOSEPH P. IDDINGS. 8vo, xi + 464 pp., 130 figures and 1 colored plate. John Wiley & Sons, New York, 1909.

The Natural History of Igneous Rocks. By ALFRED HARKER. 8vo, xvi + 384 pp., 112 figures and 2 plates. Mathuen & Co., London (1909).

When, a few years ago, four of the leading American petrographers relinquished as futile all attempts to find a natural grouping of the igneous rocks and proposed a new, precise, consistent but thoroughly artificial system of classification, doubtless many of their colleagues regretfully experienced some loss of interest in the science of petrology. Notwithstanding the gain in accurate designation afforded by the new system and the knowledge that it demanded more discriminating use of chemical data than had been generally practised hitherto, some must have felt that no amount of ingenuity and no infallibility of docketing could remove the suspicion that, after all, the calculation of an unreal "norm" in terms of certain ideal minerals might be merely a kind of game, rather suggestive of some of those played in that whimsical

country through the looking glass. At best the process appeared to be nearer akin to bookkeeping than to science.

Although Mr. Iddings of course still adheres to the "quantitative system," it is impossible to read his present volume and the equally notable one by Mr. Harker without being impressed by the substantial gains in our knowledge of rock magmas made during the last few years through the application to them of the principles of physical chemistry, and without receiving also the stimulation that comes from the prospect of still further advance. Mr. Iddings's book, it should be noted, is to be followed by a second volume on the description and occurrence of igneous rocks. The present work, however, is complete in itself and, covering so nearly the same ground as does Mr. Harker, suggests close comparison of the very interesting likenesses and differences in the two modes of treatment. It should be said at once that neither book is elementary. Both presuppose considerable knowledge of chemistry, physics, mineralogy and geology.

The difference in attitude of the two writers appears from the opening chapters. Mr. Iddings's first chapter discusses the chemical composition of igneous rocks, and is largely occupied with a description of various modes of diagrammatic presentation and camparison of analyses. Mr. Harker's first chapter deals with igneous action in relation to geology, and in it he urges that more attention should be paid to the consideration of igneous activity as a significant part of the geologic record; its manifestations should be treated as something more than mere erratic episodes interrupting the course of erosion and sedimentation. Chronological and geographical distribution, together with cycles of igneous activity are also briefly treated.

In his second chapter Mr. Iddings passes to the chemical composition of the pyrogenetic minerals which are taken up in groups corresponding to the grouping of certain elemental constituents in accordance with the periodic law of Mendeléeff. It is a little difficult to see exactly what is gained by this arrangement as compared with a classification based on mineralogic rather than chemical data. The plan leads to much repetition (acmite, for example, being described in group I (R_2O) and in group II (RO also) and separates members of isomorphous series. The chief advantage of this method of presentation is that it enables us to see into what minerals any particular element or group of elements enters.

Mr. Harker's second and third chapters take up successively volcanicity proper and igneous intrusions, the treatment being along broad geologic lines. The attempt to distinguish between forms of intrusion characteristic respectively of plateau and mountain districts is not clearly

successful. In discarding the termination *lith* in favor of *lite* in such words as *batholith* the author expressly states that he bases his choice on a preference for English rather than German spelling, forgetting apparently that *monolith* and *lithology* are good English words and that *ite* is already overworked in mineralogic and petrographic terminology. He is not entirely consistent, moreover, as he later on employs the term *xenolith*. Chapter IV contains a brief discussion of petrographic provinces, attention being particularly directed to the characteristic differences between the rocks of what Harker terms the Atlantic and Pacific branches. It must be admitted, however, that the known exceptions to the supposedly distinct areal distribution of these two general groups of rocks are numerous and continue to increase. Within these two great regions into which the surface of the globe has thus been divided are, it is pointed out, many petrographic provinces each with its special peculiarities, determined by magmatic differentiation which is primarily the result of deep-seated mechanical forces. It is shown that, so far as concerns Britain at least, petrographic provinces have not remained fixed throughout geologic time, but have undergone rearrangement in different periods.

In Chapter V, Mr. Harker discusses the mutual relations of associated igneous rocks, making use of simple and effective variation diagrams to show the changes in chemical composition observed in different groups of genetically dependent rocks. Several examples of local differentiation are presented and discussed. In chapters VI to X, he treats with admirable clearness of (1) igneous rocks and their constituents, (2) rock magmas, (3) the crystallization of rock magmas, (4) supersaturation and deferred crystallization, and (5) isomorphism and mixed crystals. This part of his work corresponds rather closely with Mr. Iddings's Chapter III, on the principles of physics and chemistry applicable to rock magmas, Chapter IV, on chemical reactions in rock magmas and Chapter V, on the separation of substances from solution. Both writers agree of course in regarding molten magmas as solutions and both summarize the results of modern research on the properties of solutions in general and particularly of those at high temperature. The important contributions of Vogt, Doelter, Roozeboom, Day and Allen, and Miers, are specially utilized. Mr. Iddings prefaces his discussion of magmas by a general review of physical chemistry, including definitions of such things as the boiling point, specific heat and diffusion. Mr. Harker assumes that his readers possess most of this knowledge or know where to find it and proceeds directly to consider the application of principles to magmas. The chapter in Mr. Iddings's book on chemical reactions in rock magmas deals with the chemical conditions under which various

minerals may form during solidification—a phase of the subject that is less fully treated in the other book. Incidentally attention is called to a fact not always appreciated, namely that, atomically, three-fifths of the average igneous rock is composed of oxygen. Both works treat fully and satisfactorily the separation of substances from solution with ample diagrammatic illustration of freezing curves, eutectic points and the effects of supersaturation on the order of crystallization. The separation of isomorphous compounds from a magma is discussed in the light of Roozeboom's researches, and explanation is given of the zonal structure often found in minerals belonging, like the feldspars, to an isomorphous series.

In Chapter XI, Mr. Harker treats briefly the structure of igneous rocks, *structure* in this usage being synonymous with what Mr. Iddings calls *texture* (or fabric) and deals with at length in his sixth chapter. There is evident difficulty in drawing a line, however, between texture and structure in Mr. Iddings's usage. For example, what are generally known as gneissic and orbicular structures are by him described as textures. This sixth chapter, as was to be expected, is particularly full and satisfactory in its treatment of spherulitic growths. A large part of the chapter, however, is devoted to an elaborate and very detailed classification of rock textures with a corresponding nomenclature. While some of the new terms, such as those proposed to express the relative proportions of phenocrysts and groundmass (perpatic, dopatic, sempatic, dosemic and persemic) may prove useful, others serve rather to illustrate the possibilities of minute classification than to supply a real demand.

Mr. Iddings cites, without special critical comment, Lane's conclusions on the relations between rate of cooling and the grain of rocks. Harker, however, points out that the underlying assumption of simple cooling by conduction disregards the important changes of temperature due to the setting free of latent heat in the crystallization of the magma.

Mr. Iddings's seventh chapter deals with the differentiation of rock magmas. The same topic forms the subject of Mr. Harker's twelfth chapter, his eleventh, on mineralizers and pneumatolysis having no analog in the companion volume. The evidence of differentiation is fully presented by Mr. Iddings, including some brief discussion of petrographic provinces. The various agencies or conditions most likely to effect changes in different parts of a body of magma are next considered. In regard to the molecular character of compounds that may diffuse and concentrate in any part of a magma solution, Mr. Iddings shows that these must correspond to definite mineral compounds. He thus repudiates his earlier (1892) conclusion, criticised adversely by Harker, that

the movement takes place as simple oxide molecules. Mr. Iddings considers that differentiation is effected chiefly while the magma is entirely fluid, by changes in temperature, pressure and gaseous contents. These primary changes will affect the density, viscosity, osmotic pressure, saturation and crystallization, and chemical equilibrium of the magma and will determine its kind of solidification or texture. Mr. Harker's views do not appear to be fundamentally different, although he lays special emphasis on mechanical stresses followed by fractional crystallization and diffusion. Both agree that in the history of rock magmas, so far as it is legible to us, important modifications of composition by the assimilation of foreign intratelluric material is, in Harker's words, "only an exceptional incident." Various considerations lead to the conclusion that most magmas are intruded at temperatures far too low for extensive fusion of the invaded rocks. Differentiation as both writers show is primarily dependent upon deep-seated mechanical stresses that permit movement of magma originally under such pressure and temperature as to be in practically a static condition. In this connection Iddings makes the interesting observation that the conclusion of Hoskins as to the impossibility of open cracks existing below a depth of 10,000 meters is based upon the assumption that the cracks are filled with water, and that where the filling material is as heavy as the wall-rock, fractures are possible in the supposedly solid earth wherever a tendency to parting may be present. Where proper stresses are set up it is conceivable therefore that fractures may form and be immediately filled by the slightly hotter, potentially liquid magma from below. In such way Mr. Iddings supposes that the primary magma makes its way upward and, after undergoing more or less differentiation in its course, finally reaches the surface or solidifies as an intrusive mass. The forces of eruption, as he remarks, are of the same order of magnitude as those causing crustal disturbances and are intimately related to the latter. His whole treatment of this necessarily rather speculative subject is very interesting and suggestive.

In Chapter VIII, Mr. Iddings describes briefly the modes of occurrence of igneous rocks and under the heading of *Structure* gives an excellent account of prismatic parting (columnar structure) and its origin.

The last third of Mr. Iddings's book, constituting Part II, is devoted to the nomenclature and classification of igneous rocks. A brief historical sketch is followed by a chapter on the current mineralogical-texture classification, such as is used in the works of Rosenbusch and Zirkel, and the rest of the volume contains an exposition of the "quantitative system" of classification. As this has been familiar to petrog-

raphers since 1903 there is no need to recapitulate it here. Mr. Harker's final chapter also deals with classification. He gives the desiderata of an ideal system, laying special emphasis upon the importance of eutectic ratios as originally suggested by Becker. In his opinion the final or satisfactory system will be a product of slow growth and not, like the American system, a manufactured scheme based on *a priori* considerations.

Whatever opinions one may hold on the question of rock classification there can be no doubt of the great value and suggestiveness of both of these books. Written contemporaneously from different points of view, they should be read together to profit from them most. If Mr. Iddings's volume is, as is natural in one intended as the first part only of a comprehensive treatise, the more closely packed with data, Mr. Harker's, on the other hand, is the more readable and is certainly the more stimulating work of the two. The latter is thoroughly familiar with such modern investigations in physical chemistry as relate to rock magmas and has applied their results where his subject requires them rather than attempting to present a complete summary of them in any one place. Both books are indispensable to petrologists and both are admirable examples of effective presentation of a subject whose connection with life, though real and fundamental, is not so obvious as to give it the immediate interest of the biological sciences.

F. L. RANSOME.

The Geology of Ore Deposits. By H. H. THOMAS, M.A., B.Sc., and D. A. MACALISTER, Assoc. R.S.M. Edwin Arnold, publisher, London, 1909. Small octavo, 416 pages, 65 text-figures in black and white.

One opens this moderate sized and neatly bound volume in hopeful anticipation that it may supply a long-felt need of the teacher of economic geology and the student of general geology for a modern yet elementary text-book on ore deposits. As one turns the leaves this hope is strengthened by the judicious selection evident in the sixty-five black and white plates and the modern general plan of treatment of the subject. The print and the paper also are excellent.

After an introductory chapter in which the authors recognize "that any classification can only be arbitrary and that there are many instances of an ore deposit being equally well assignable to two positions in the scheme of classification" they proceed to develop the subject under the following chapter headings: I, Ores Due to the Differentiation of Igneous Magmas; II, Pneumatolysis; III, Hydatogenesis—Deposits Formed by After-eruptive Actions which are not Pneumatolitic; IV, Ores Due to Metasomatic Replacement; V, Bedded Ores Due to Precipitation; VI,

Metamorphic Ore Deposits; VII, Secondary Changes in Ore Deposits Apart from Metamorphism; VIII, Detrital and Alluvial Deposits.

The restriction of metasomatism by these authors to chemical replacements accomplished only by cold circulating waters and the restriction of the term metamorphism to include only dynamic and contact metamorphic changes, will hardly be generally agreed to.

Under each heading the principal types of changes are briefly defined and a large number of examples cited.

In the selection of examples the authors display a wide familiarity with the literature of economic geology, and although English deposits are given precedence, as natural in an English book, the important deposits of other parts of the world are given adequate representation. The great numbers of examples cited appear to the reviewer to be the weak point of the book and a feature which will seriously impair its usefulness. The multiplicity of examples wearies the reader and encourages "skimming"; on the other hand, each deposit is described so briefly that no distinct mental picture of it is retained. This method of treatment would be more excusable if with each brief summary was given a reference to the publication where the detailed characters are described, but the book contains not a single reference of any sort, so that it has no value whatever as a guide to the literature of the subject. In the opinion of the reviewer the book would be of much greater service to the student if, instead of the many examples, a few type occurrences had been selected and described at more length.

At least an elementary knowledge of geology is presupposed on the part of the reader, many technical geologic terms being used without definition. The book will find its principal use as a reading lesson for the general geologist who wishes to know something of the theory and distribution of ore deposits.

EDSON S. BASTIN.

U. S. GEOLOGICAL SURVEY,
December 28, 1909.

The Metallurgy of the Common Metals—Gold, Silver, Iron, Copper, Lead and Zinc. BY LEONARD S. AUSTIN. Second Ed. 8vo, 500 p. Ill. Mining and Scientific Press, San Francisco. $4.00.

The chief changes from the first edition are in the description of the cyanide process, the metallurgy of zinc and plant and equipment. Additions occur in the manufacture of wrought iron and steel, the refining of zinc and the electrolytic refining of lead.

The book attempts to cover so wide a field in 500 pages that all details unnecessary for a broad view of the subject have been omitted,

but a comprehensive summary is the result, as the following abstract of the contents will show.

Part I deals with general considerations, ores, their treatment, thermo-chemistry, fuels and their production, sampling, crushing and grinding. Part II covers roasting. Then follows sections on gold, silver, iron smelting, copper, lead and zinc. Part IX deals with the refining of metals, lead, copper, parting of gold and silver, manufacture of wrought iron and steel, electrolytic lead by the Betts Process. The last two sections take up plant and equipment, and the commercial aspect of metallurgical work.

The author sets out to discuss the principles of metallurgy and illustrate them from current practice, giving a broad, solid foundation to the general student. Such he has done and as such the book well fulfils its purpose, being clearly written and well illustrated, and flow sheets given wherever processes are complex.

The value of the book, however, might have been greatly increased, and its size hardly augmented, had there been given a page or so of chief references at the end of each chapter.

WILLIAM CAMPBELL.

RECENT LITERATURE ON ECONOMIC GEOLOGY.

COMPILED BY

G. F. LOUGHLIN, J. A. ALLAN, and S. J. SCHOFIELD.

METALLIFEROUS DEPOSITS.

COPPER.

Notes on Mother Lode Mine in British Columbia. By R. H. ALLEN. Eng. and Min. Jour. Vol. LXXXVIII., No. 23, p. 1101.

The ore occurs as an immense body, or series of bodies, lying along the contact between a white crystalline limestone and a green fissile epidotic material, which may be either altered argillite or green-stone tuff. The ore consists of magnetite, chalcopyrite, and pyrite, intermixed with calcite, actinolite, garnet, epidote, and quartz, and is a metasomatic replacement of both wall rocks. S.

The Centre Star Group of Mines, Rossland, B. C. By R. H. ALLEN. Eng. and Min. Jour. Vol. 89, No. 1, p. 17.

The country rock is a series of Carboniferous sediments, chiefly slates, cut by a monzonite which is surrounded by a border of augite porphyrite and diorite-porphyrite. The ore-bodies occur in both the sedimentary and igneous rocks and are impregnations and replacements of the country rock. The ores are pyrrhotite, pyrite, and chalcopyrite, and were deposited from ascending heated solutions. S.

The Whitehorse Copper Belt, Yukon Territory. By R. G. MCCONNELL. Can. Geol. Surv. Bull. No. 1050, 1909. 58 pages with maps and illustration.

These ore-bodies belong to the type of contact metamorphic deposits, and occur along the contact of granite and limestone. The contact minerals are magnetite, hematite, bornite, and chalcopyrite. These deposits differ from ordinary contact deposits in that the intrusive is itself intensely mineralized over a large area. Small bodies of ore are even found wholly enclosed in the granite. Deposition is due to liquid and gaseous emanations from the cooling intrusive

magma. The mineralizing solutions have ascended through the porous limestone and along joints in the previously hardened portion of the intrusive. Future development is encouraged. A.

Copper Deposits of Silverbell, Arizona. By C. F. TOLMAN, Jr. Min. and Sci. Press. Vol. 99, No. 22, pp. 710–712. 1909.

States briefly that the ores occur in (1) contact bodies in limestones; (2) disseminations; (3) fissure veins in alaskite-porphyry; (4) fissure veins at some distance from the porphyry. The first of these seems to be the most important. The ore bodies occur as irregular lenses along dikes of rhyolite-porphyry in the limestone. The ore consists of chalcopyrite, pyrite, molybdenite, and wulfenite. The writer states that the ore is primary and that there is no sign of secondary enrichment. A.

Mining in the Santa Rita District, New Mexico. By C. A. DINSMORE. Min. World. No. 21, Vol. XXXI., pp. 1028–29. 1909.

Briefly notes that extensive ore bodies have been located in the "porphyry." These deposits have been followed down for several hundred feet, and are frequently located in the valleys. A.

GOLD.

The Geology of the Goldfields of British Guiana, by J. B. HARRISON, **with historical, geographical, and other chapters** by F. FOWLER and C. W. ANDERSON, **and an appendix giving the laws and regulations concerning the mining industry.** Dulau: London. 1908. 8vo, 10 + 320 pp. Price 5s.

Describes general topography, geology, and petrography, descriptive geology of the various districts, and the occurrence and origin of the gold. The gold is believed to be derived from basic igneous rocks, and to be present in the soil waters. Experiments in proof of the latter are described. (Geol. Zent., 13, 10, 1909, p. 452.) L.

Notes on the Rainy River District, Ontario. By W. L. FLEMING. Eng. & Min. Journal. Vol. 88, No. 22, p. 1064.

The workable ores occur in shear zones of a N.E.–S.W. strike in green diorite. The gold occurs both free and as auriferous pyrites in both quartz and diorite. Traces of platinum are found in all ores. S.

Quartz Mining in Yukon Territory. By G. A. R. LEWINGTON. Min. and Sci. Press. Vol. 100, No. 1, 1910, pp. 65–66.

This deposit has been called a stockwork paralleling a fissure vein in schist. The gold occurs in the fissure vein, which consists of 4 feet of quartz on the footwall with 10 feet of blue clay on the hanging. The values extend to the hanging-wall. A.

The Boicza Gold Mines in Hungary. By N. B. KNOX. Min. and Sci. Press. Vol. 100, No. 1, 1910, pp. 31–34.

Briefly states that the country rock is a complex of melaphyr and quartz-porphyry, which is more or less kaolinized and propylitized. The ore occurs in four types—(1) "gauch" veins, with the gold in the cementing material; (2) stockwerk; (3) normal fissure veins; (4) a combined fissure and stockwerk. A.

Report upon the Auriferous Deposits of Barrambie and Errolls and Gum Ceek and Wiluna. By C. G. GIBSON. Geol. Surv. of Western Australia. Bull. No. 34, pp. 40, 2 maps, 3 plates, 6 photographs.

The last named locality is the most important, here the ore deposits are of two types: (1) quartz reefs; (2) "lodes." The "lodes" are sheared zones along which the auriferous solutions passed. Within the zone of weathering, the rock is much shattered and solutions have spread over a larger extent, causing the ore-body to appear larger than it actually is. The writer considers that the solutions had a deep-seated origin. A.

Gold Fields of Surigao Peninsula, Mindanao. By M. GOODMAN. Min. World. No. 20, Vol. XXXI., 1909, pp. 977–978.

The country rock consists of chloritized and serpentinized schists which have become disintegrated. The placer gold is derived from quartz and calcite stringers which are numerous in the schists. The benches that are worked are situated from ten to thirty meters above the creek. A.

The Gold and Copper Deposits of the Phillips River, Goldfield. By H. P. WOODWARD. Geol. Surv. of West Australia. Bull. No. 35, pp. 104, 2 maps, 8 plates, 7 photographs.

The geology and mines are described in some detail, but very little is said about the ore deposits. The ore occurs in cupriferous and auriferous dikes, also in silicious and ferruginous material, filling fractures. A.

The Black Range Mining District, New Mexico. By J. W. WRIGHT. Min. World. No. 20, Vol. XXXI., 1909, pp. 979–981.

States somewhat briefly that the ore is found in fissures, one of which is traceable for about fifteen miles. The ore bodies are in granitoid rocks and are highly silicious. The writer states that ascending solutions have deposited in these fissures quartz, pyrite, and chalcopyrite, while later surface waters have oxidized the sulphides and set the gold free. A.

IRON.

Iron Ore Deposits along the Ottawa and Gatineau Rivers. By F. CIRKEL. Mines Branch of the Dept. of Mines, Ottawa, Canada, 1909. 147 pages, with maps and illustrations.

Describes in some detail various iron ore deposits in this area. The method of treatment of the ores is also discussed. A.

LEAD.

Missouri Bureau of Geology and Mines, Vol. IX., Part I. and II. E. R. BUCKLEY.

The geology and ore deposits are described in detail. The original sources of the metallic minerals are the granite, rhyolite, and diabase of Pre-Cambrian Age. The lead was dissolved from these igneous rocks and precipitated partly in the igneous rocks themselves and partly in the ocean along with the sediments. This process was repeated during succeeding periods. Final concentration was caused by descending waters depositing the galena in pre-existing cavities. S.

MANGANESE.

Uber das Vorkommen von Manganerzen bei Wandelitzen nächst Völkermarkt in Kärnten. By R. CANAVAL. Jahrb. d. naturhist. Landesmus von Kärnten. H. XXVIII., 1909, pp. 357–368.

Describes stratigraphy and ore occurrence. The ore is psilomelane in residual soil, resting directly upon limestone, but derived in part from green schist which overlay the limestone. (Geol. Zent., 13, 11, 1909, p. 507.) L.

TUNGSTEN.

The Main Tungsten Area of Boulder Country, Colorado. By R. D. GEORGE. Proc. of the Col. Sci. Soc. Vol. IX., pp. 181–216.

Describes somewhat fully the various tungsten minerals with analyses of each. The country rock is granite and gneiss. The ore is found in fissures caused by frequent movements evident in the district. The ore minerals occur as a crustification about the rock fragments; in irregular granular masses; and in crystal form. A.

NON-METALLIFEROUS DEPOSITS.

ASBESTOS.

The Production of Asbestos in Canada. By J. MCLEISH. Can. Min. Jl. Vol. 30, No. 23, pp. 714–717, 1909.

In a series of tables, in concise form, it gives the production of asbestos in Canada since 1880. These tables show a steady increase

in the total production of the previous year. The total production of asbestos and asbestic in 1908 amounted to 90,773 tons (short) valued at $2,573,335. About four fifths of the output was exported to the United States. A.

ASPHALT.

Asphaltgänge im Quartzporphyr von Dossenheim bei Heidelberg. By W. SALOMON. Ber. über die Versamml. des Oberrh. geol. Ver., 42. Versamml. zu Heidelberg, 1909, pp. 116–122.

Asphalt, coating quartz crystals, is found in joints of the porphyry. The origin, whether organic or inorganic, is not certain, though the author favors the inorganic. Chemical analyses by E. Ebler are appended on p. 123. (Geol. Zent., 13, 12, 1909, p. 547.) L.

Ozokerite in Utah. By H. W. MACFARREN. Min. and Sci. Press. Dec. 11, 1909, pp. 789–790.

Very briefly describes the deposit as unique on this continent; a similar deposit is worked in Galacia in Austria. The deposits lie in shear-zones, shales, shaly sandstone, and limestones of Tertiary age, and are contiguous to extensive deposits of carbons and hydrocarbons. The ozokerite is said to be the residual product of petroleum, having a paraffin base. Since it was forced into the fissures, the lighter hydrocarbons have become volatilized. A.

CLAY.

China-Clay and Fire-Clay Deposits in the Rajmahal Hills, India. By M. STUART. Rec. Geol. Surv. of India. Vol. XXXVIII., Pt. 2, 15½ pages, 1909.

DIAMOND.

The Diamond Deposits of Luderitzland, German South-West-Africa. By H. MERENSKY. Trans. Geol. Soc. So. Africa. Johannesburg, 1909, Vol. XII., pp. 13–23.

Describes geologic structures of the region and the occurrence of the diamonds. The latter are found in a residuum of wind-eroded Cretaceous sandstone. (Geol. Zent., 13, 11, 1909, p. 455.) L.

COAL.

The Coal Fields of Manitoba, Saskatchewan, Alberta and eastern British Columbia. By D. B. DOWLING. Can. Geol. Surv. Bull. No. 1035, 1909. 111 pages, with illustrations and map.

The writer describes in detail the coal-bearing formations and the various seams. Extensive and useful analyses of the coal from vari-

ous seams are given. The three coal horizons are: (1) Edmonton formation (in Alberta), and Laramie (in Saskatchewan); (2) Belly River (Judith River) formation; (3) Kootanie formation. An estimate has been made of the coal content in these provinces as follows: Alberta, 89,330,000,000 tons; Saskatchewan, 18,000,000,000 tons (lignite); Manitoba, 160,000,000 tons (lignite); Eastern British Columbia, 36,000,000,000 tons (bituminous). A.

GRAPHITE.

The Santa Maria Graphite Deposits, Mexico. By F. L. HESS. Min. World. Vol. XXXI., No. 22, pp. 1078–80, 1909.

The graphite deposits occur as irregular lenses, most of which vary from 8 to 10 feet in thickness, while a few are even much thicker. The wall rock is either sandstone or granite. In some places it is impregnated with graphite, while in others it is absent. A.

MEERSCHAUM.

Über den bosnischen Meerschaum. BY F. KATZER. Berg- u. Hüttenmänn. Jahb. der K. K. Mont. Hochschulen. 1909, H. 1, pp. 1–24.

Describes two meerschaum deposits. One forms irregular masses and pockets in magnesite veins which cut serpentine; the other is a conglomerate of which meerschaum is a constituent. (Geol. Zent., 13, 12, 1909, p. 547.) L.

PHOSPHORUS MINERALS.

Note sur les filons de phosphorites de Logrosan dans la province de Caceres. By P. CHAUFFAT. Mém. de la Société belge de géologie, de paléontologie, etc. T. XXIII., 1909, pp. 97–114.

The author describes the veins, long abandoned because of litigation, and shows that the values are not limited, as previously supposed, to shallow depths. (Geol. Zent., 13, 11, 1909, p. 508.) L.

Les phosphates du Pacifique. By H. COURTET. Bull. Soc. Acclimatization. 1909, pp. 279–288.

Reviews history of discovery; shows the total production (300,000 tons in 1907); estimates the approximate amount of material available in certain deposits (totalling 25 to 28 million tons); assigns origin to the action of guano on the subjacent rocks. (Geol. Zent., 13, 11, 1909, p. 58.) L.

WATER.

Geology and Underground Waters of South Dakota. By N. H. DARTON. Water Supply Paper, No. 227. U. S. G. S. 149 pages with illustrations and maps.

Describes fully the various sedimentary formations in the state, determined in part from deep well borings, and discusses the probable supply of artesian waters. The Dakota sandstone, which is the most extensive formation, is the principal source of the artesian water, while the Brenton shale is taken as an horizon of second importance. A.

Surface Water Supply of the United States, 1907–8. Part II., South Atlantic Coast and Eastern Gulf of Mexico. Prepared under the direction of M. O. LEIGHTON by M. R. HALL and R. H. BOLSTER. Water Supply Paper, No. 242. U. S. G. S. 1909, 215 pp.

Describes the drainage basins of many of the more important rivers in the South Atlantic States, and in eastern Gulf of Mexico. The stream-flow data serves of use in problems of navigation, irrigation, domestic water supply, water power, swamp and overflow land drainage, and flood-prevention. A.

REGIONAL REPORTS.

Les mines de l'Afrique occidentale française. By J. CHAUTARD. Bull. Office Colonial. June, 1909. Supplément.

Describes the occurrence of several metallic and non-metallic products. Of these only gold, iron, and petroleum are of present economic importance. Further exploration may discover workable deposits of manganese, aluminum, copper, phosphates, and salt. (Geol. Zentralb., 13, 11, 1909, pp. 505–506.) L.

Die Erzlagerstätten von Cartagena in Spanien. By R. PILZ. Zeit. f. prakt. Geol. Jg. XVI., 1908, H. 5, pp. 177–190.

Describes the general geology and the ore-deposits. The latter are chiefly argentiferous galena, blende, and pyrite, with secondary cerussite and limonite; also tin ore with barite. The ores are thought to be secondary after stanniferous pyrite.

A Descriptive Sketch of the Geology and Economic Minerals of Canada. By G. A. YOUNG. Can. Geol. Surv. Bull. No. 1085, 1909, 146 pages, 82 illustrations and 2 maps.

Map No. 1042, on a scale of 100 miles to the inch, shows the localities at which economic minerals have been found, while No. 1084 outlines the geology of the Dominion as known to-day. The writer divides the area into six divisions, and describes under each the economic geology, also the character and mode of occurrence of certain deposits in tabulated form. These divisions are: (1) The Applachian Region; (2) St. Lawrence Lowlands; (3) Laurentian Plateau Region; (4) Arctic Archipelago; (5) The Interior Continental Plain; (6) The Cordilleran Region. A.

ORE-DEPOSITS.

Outcrop of Ore-bodies. By W. H. EMMONS. Min. and Sci. Press. Vol. 99, No. 23, pp. 751–754 and Vol. 99, No. 24, pp. 782–787, 1909. Illus.

This is an interesting and instructive treatise and one full of facts and examples. The writer considers the discovery and study of the outcrop of the ore-body of prime importance in resolving the economic history of the district. From a study of the "topographic expression" of the outcrop, the writer shows how it is possible to interpret the extent of the deposit and the changes which may take place with depth. Useful notes are given on the outcrops of gold, silver, copper and lead deposits. A.

Lehre von den Erzlagerstätten. By R. BECK. Dritte, stark umgearbeitete Auflage in zwei Bänden. Ersten Band, mit 205 Figuren und einer Gangkarte. Zweiter Band, mit 318 Figuren. 32 Mark. (Berlin Gebrüder Bornträger.)

Deals with genesis and characters of ore deposits. A.

UNCLASSIFIED.

Granites. By G. SURR. Min. and Sci. Press. Vol. 99, No. 22, pp. 712–14. 1909.

Gives an interesting outline of the character, and the mode of occurrence and formation of the different varieties of granite; also notes the minerals of economic value which may be associated with them. A.

Mineral Resources of the United States for 1908. U. S. G. S. 1909. Advance chapters on

(1) The cement industry. By E. C. ECKEL.

(2) Antimony, Arsenic, Bismuth, Selenium, and Tellurium. By F. L. HESS.

(3) Tungsten, Nickel Cobalt, Vanadium, Titanium, Molybdenum, Uranium and Tantalum. By F. L. HESS.

(4) Mineral Paints. By E. F. BURCKARD.

(5) Precious Stones. By D. B. STERRETT.

(6) Tin. By F. L. HESS.

(7) Sulphur and Pyrite. By W. C. PHALEN.

(8) Petroleum. By D. T. DAY.

(9) Silver, Copper, Lead, and Zinc in the Central States. By B. S. BUTLER and C. E. SIEBENTHAL.

(10) Platinum. By D. T. DAY.

(11) Mica. By D. B. STERRETT.

(12) Gas, Coke, Tar, Ammonia at Gas Works and in Retort Coke Ovens and of Gas and Tar at Water Gas Works. By E. W. PARKER.

(13) Iron Ores, Pig-Iron and Steel. By E. C. HARDER and W. T. THOM.

(14) Asbestos. By J. S. DILLER.

(15) Gypsum and Gypsum Products. By E. F. BURCHARD.

(16) Graphite. By S. T. BASTIN.

(17) Glass sand, other sand and gravel. By E. F. BURCHARD.

(18) Fluorspar and Cryolite. By E. F. BURCHARD. A.

SCIENTIFIC NOTES AND NEWS[1]

DR. ALBERT JOHANNSEN, of the U. S. Geological Survey, succeeds Professor J. P. Iddings in the chair of petrology, department of geology, at the University of Chicago, beginning with the Spring term.

J. L. RICH is instructor in physical geography at Cornell University this winter.

F. H. KAY is on temporary leave from the U. S. Geological Survey and engaged in commercial geology in Mexico at present.

F. C. SCHRADER returned to Washington at the close of the year, after spending two months investigating gold placers in the Clearwater River region of Idaho.

SYDNEY H. BALL, directing geologist of the Société Internationale Forestière et Minière du Congo, has opened an office as a mining geologist at 71 Broadway, New York.

DONALD F. MACDONALD, junior geologist, U. S. Geological Survey, is this winter in charge of the work in geology at Tulane University, New Orleans.

AT THE RECENT annual meeting of the New York Academy of Science Professor James F. Kemp was elected president.

RESULTS of two seasons work investigating the slate deposits of the State have been published recently by the Geological Survy of Arkansas. This work, which was done in coöperation with the U. S. Geological Survey, was called for by the General Assembly in response to the increasing attention which the slate deposits had attracted in recent years from prospectors and

[1] Geologists, mining engineers and others interested in applied geology are invited to keep the editor informed of new investigations of mining districts or scientific studies undertaken by them, together with such other scientific and personal items as may come to their notice.

operators. The report is by Professor A. H. Purdue, State Geologist, and includes a bibliography of the geology of Arkansas by Dr. J. C. Branner.

A MINING EXPERIMENT STATION has been created as a part of the School of Mines at University of North Dakota and a branch Mining Experiment Sub-station established at Hebron, N. D. Conclusions reached through experimental work in the laboratories at the School of Mines will be put to a practical working trial at the testing-out plant of the sub-station. Certain laboratories will be set aside for experimental and research work on gas, coal, clay, building materials, cements, etc., and for this work the laboratories will be among the very best equipped in America.

The work which will be taken up most vigorously during the coming year will be investigations and practical tests of cheap and satisfactory methods of briquetting lignite, of the best methods of burning lignite, and to determine the possibility of utilizing lignite for producing gas for light, heat and power, Attention will be given also to the utilization of the high grade clays of the state for the manufacture of a variety of wares. A complete briquetting plant has been designed and is now being built. The press will have a capacity of two tons of briquettes per hour.

A BILL was introduced in the House of Representatives, January 4, appropriating the sum of $160,000 to be expended under the direction of the Secretary of the Interior, for the construction, equipment, and maintenance of additional mine rescue and experiment stations.

THE FIRST REPORT of the Colorado Geological Survey, which was organized in May, 1907, shows a commendable amount of work accomplished by R. D. George and his staff in a short time and promises well for the future. It includes reports on The Main Tungsten Area of Boulder County, The Montezuma Mining District, The Foothills Formations of Northern Colorado, and The Hahns Peak Region. Among plans for the future,

Professor George proposes to publish bulletins for school use descriptive of the physical geography, geology, and natural resources of the State, and to present each high school with a set of rocks and minerals which shall represent the geology and mineral wealth of the State and illustrate the bulletins.

F. B. TAYLOR, of Fort Wayne, Ind., was in Washington early in January making arrangements for the completion of the Niagara Falls folio, work on which was interrupted by the ill health of G. K. Gilbert. Mr. Taylor will review the Pleistocene geology and E. M. Kindle the Paleozoic geology during the coming Spring.

CHAS. BUTTS, of the U. S. Geological Survey, is spending the winter in Birmingham, Alabama, mapping areal geology in that vicinity.

THE ILLINOIS STATE GEOLOGICAL SURVEY has just published the second of its educational bulletins designed for the use of students of physical geography and geology in the schools, and for the education of the people by describing physical features of the land and explaining the manner in which they have been developed. This report, bulletin No. 11, is entitled, "Physical Features of the Des Plaines Valley," by James W. Goldthwait. It is written in a delightful style, admirably illustrated, and should prove not only entertaining but of value to a considerable number of people both in and out of the State. Besides the educational value of the report it has practical value in view of the notes concerning floods, amount of stream flow, and area inundated.

AT THE MEETING of the New York Academy of Sciences, Monday, January 3, 1910, at the American Museum of Natural History, the following papers of interest to economic geologists were given: Geological Notes on Northern Brazil, by Geo. W. Tower, Jr., Brief Notes on Some of the Geological Aspects of the Province of Bahia, Brazil, by Dr. Henry S. Washington.

WORK OF THE GEOLOGICAL SURVEY IN 1909.

Annual Report of the Director.—Land classification, examination of water resources, investigations of mine accidents, and tests of mineral fuels and building materials formed special features of the Geological Survey's work during the fiscal year 1909.

Surveys of Coal Lands.—The annual report of the Director of the Survey, just issued, states that the General Land Office depends on the Survey to furnish detailed valuations for every 40-acre tract of coal land that is placed on the market. The tendency of legislation is to separate the mineral and the agricultural values of the land; the surface rights may be separated from the right to mine the underlying coal. The purpose of the Survey's work in the coal lands is to expedite the restoration to agricultural entry of land that is found to be barren of coal, although necessarily included in the withdrawals, and to promote the development of the coal lands. About 6,875,000 acres of non-coal land in Colorado, Wyoming, and Montana have thus been released to agricultural entry, and selling prices have been placed on about 1,500,000 acres of coal land in the same States, at a valuation of nearly $94,000,000, an advance of 200 per cent. over the minimum prices fixed by law.

Withdrawal of Water-Power Sites.—In addition to its classification work in coal, oil, phosphate, and metalliferous lands the Survey is also examining sites for undeveloped water powers to which the Government still holds the title, and on its recommendations prior to October 1 the Secretary of the Interior temporarily withdrew from entry the power sites on 42 streams.

Non-Irrigable Land Opened to Entry.—The water-resources investigations are also of national importance in connection with the administration of the enlarged homestead act, which authorizes the Secretary of the Interior to open to such entry all public lands that are not economically irrigable.

Mine Accidents.—The Survey conducts a testing station at Pittsburg, where special examinations of the causes of mine accidents are made, as well as tests of explosives and of safety

lamps and other mining appliances, including rescue apparatus.

Tests of Fuel and Building Material.—Tests of coals and of building materials are also made at Pittsburg. The larger part of the fuel used by the Government in its many buildings, costing annually about $5,000,000, is now purchased under specifications prepared by the Survey, and materials for Government engineering and construction work amounting to $50,000,000 have been examined at the Pittsburg station.

Topographic and Other Work.—The report gives detailed accounts of the progress of work on the topographic and geologic atlases of the United States, of special geologic and hydrographic surveys, including work in Alaska, and of statistical work on mineral resources.

POCKET EDITION OF GEOLOGIC FOLIOS.

Geological Survey Issues Volumes of Geologic Atlas in New Form.—The United States Geological Survey has just adopted an octavo or pocket form for its geologic folios—the separate parts of units of the geologic map of the country which is now in preparation. These separate parts have heretofore been published only in folio form—about 18 to 21 inches—but as a result of correspondence with geologists, engineers, teachers, and librarians throughout the country the Survey will print also a field edition of all future issues of these publications, in size about 6 by 9 inches. The folio form is satisfactory for office and library use but a smaller form is desired for use in the field.

Contents of the Folios.—Each folio contains a topographic map of the area considered and maps showing its areal and structural geology, with a short descriptive text. Some folios include also maps showing mineral resources and underground water, as well as geologic sections and other diagrams and illustrations.

A Library and a Field Edition.—In the new form the maps are folded and inclosed in a pocket. Many librarians and instructors prefer the unfolded maps, but most mining men desire a pocket edition, so both editions will hereafter be published by the Survey. The new field edition is bound in substantial manila

board, which forms also the pocket. The maps are printed on a special paper that will bear refolding and handling.

Although the folios of the geologic atlas are prepared primarily for educational and technical purposes they have also been of interest to many nontechnical people who have desired to obtain some knowledge of the geology of the areas in which they live, but the large size of the folios has served to keep them out of a bookcase. The folios in the new form can easily be preserved on ordinary shelves with other books.

Folios Now Ready in the Field Edition.—Five folios in the field edition are now ready for distribution, the Belle Fourche (South Dakota), the Aberdeen-Redfield (South Dakota), the El Paso (Texas), the Trenton (New Jersey), and the Jamestown-Tower (North Dakota), numbered respectively 164, 165, 166, 167, and 168.

The price is the same for either edition—25 cent each, the cost of paper and printing.

Separate Geologic Maps.—A few extra copies of the areal geologic maps that accompany the folios of the field edition are printed and can be had separately, unfolded, for 5 cents each.

THE DIVISION OF MINES, BUREAU OF SCIENCE, MANILA.

During the past year the staff of the Division of Mines has been completed by the arrival of Mr. Frank T. Eddingfield (Columbia) as mining engineer and Mr. Wallace E. Pratt (University of Kansas) as assistant geologist. Parties have been in the field engaged in the following pieces of work:

Mr. Ferguson has continued his field work on the geology of the Aroroy Mining District of Masbate Island, and reconnaissance of the island. Dr. Adams spent six weeks in the Island of Leyte, making artesian water investigations and a general reconnaissance of the geology of the island. He has also completed a reconnoissance of southwestern Luzon, begun in 1908, and a preliminary investigation of the Tayabas Oil field.

Mr. Eddingfield spent the month of June in the Paracale

Mining District, directing the triangulation work just begun there.

Dr. Smith spent two weeks in Masbate making an inspection of the work going on there. During the remainder of the time he has been engaged in completing his report on the geological reconnaissance of Mindanao and Sulu; in the preparation of a bulletin entitled "Salient Features of the Geology of the Philippines" and in carrying on his studies for a monograph on Philippine Tertiary Fossils. In December Dr. Smith made an inspection of the Camarines gold field and the Batan Island coal field.

The field work planned for the coming year is as follows:

Detailed mapping in Benguet Gold Field and reconnaissance of surrounding territory, by Dr. Smith and Mr. Eddingfield.

Reconnaissance in Northern Luzon, by Mr. Ferguson.

Reconnaissance of southeastern Luzon with particular reference to clay deposits, by Dr. Adams and Mr. Pratt. Later on Dr. Adams will begin geological work in the Paracale Gold district.

In addition special laboratory investigations, such as cyanide tests, electric furnace smelting of iron ores, paleontology, etc., preparation of reports, statistical work are under way.

The results of the work of the Division of Mines appear in the following forms: I., Press Bulletins; II., Annual Bulletin of Mineral Resources; III., Special articles in the Philippine Journal of Science, Section A.

Professor J. P. Iddings is now in the Philippines studying the igneous rocks of the Islands. Besides examining the large collection of slides of the Division of Mines, Bureau of Science, he is making a number of field trips with the members of the Division of Mines. In December he accompanied Dr. Smith to the Camarines Gold Field to examine the gneisses and schists which occur there, and also the volcanic area of southeastern Luzon, of which Mount Mayon is the center. Professor Iddings expects to spend the larger part of the winter in the Philippines, proceeding in the spring to Java.

WARREN D. SMITH,
Chief, Division of Mines.

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